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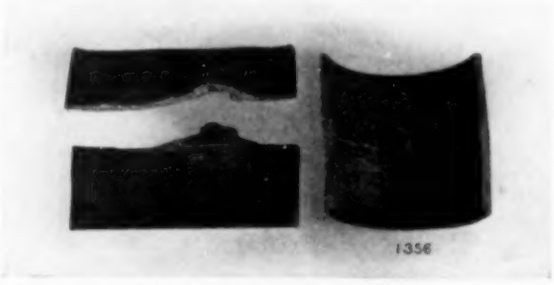
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Metallurgical and Chemical Engineering

A Consolidation of ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

VOL. XIII — NEW YORK, MARCH, 1915 — NO. 3

PUBLISHED MONTHLY BY THE
McGraw Publishing Company, Inc.
JAMES H. MCGRAW, President.
A. E. CLIFFORD, Secretary.
JOHN T. DEMOTT, Treasurer.
239 West 39th Street, New York.

TELEPHONE CALL, 4700 BRYANT.
CABLE ADDRESS, METCHEM, NEW YORK.

ROCKY MOUNTAIN OFFICE.....421 Boston Bldg., Denver, Colo.
PACIFIC COAST OFFICE.....502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE.....Old Colony Building
CLEVELAND OFFICE.....Leader News Building
PHILADELPHIA OFFICE.....Real Estate Trust Building
LONDON OFFICE.....Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. M. MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $2.00; for all other countries, $2.50. (European exchange, 10 shillings, 10 marks, 12.50 francs.)

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Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

NEW YORK, MARCH, 1915

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Copper and the Flotation Process

One of the most suggestive points in Mr. Mathewson's notes on present tendencies in copper metallurgy, published elsewhere in this issue, is the effect of concentration by flotation. From its position as an intermediate process between gravity concentration and smelting, flotation exerts an influence in both directions. In ore-dressing it has proved the method par excellence for concentrating slime. Hence the production of slime in crushing and grinding for gravity concentration is no longer the bugbear that it has been in recent years. A natural conseequence is an increased production of fine concentrates unsuited to blast furnace treatment, but reverberatory smelting removes any difficulty on this score. The efficiency of flotation, plus the improvements in reverberatory smelting, is modifying milling ideas by reducing the upper limit of size at which gravity concentration has been practiced. The combination points to more fine grinding and slime concentration, and the relegation of the blast furnace from its eminent position.

Another interesting possibility is the effect of flotation on leaching processes. At a time when hydrometallurgy is just getting its stride and finding acceptance among metallurgists, flotation rises as a definite competitor and threatens the popularity of copper leaching. Progress in flotation is being made so rapidly that the actual application of leaching processes may halt to await developments. With such results as flotation has shown at Anaconda it may be a question whether the elaborate roasting-leaching process developed there will be long continued. In the case of oxidized copper ores also, flotation may forestall leaching if the process of converting carbonates and oxides to sulphides, and floating the latter, is successfully developed. Further, while leaching may be profitably applied to certain ores, the character of ore-bodies changes with depth and oxidized ores give place to sulphides or mixtures which will be unsuited to leaching but may be amenable to flotation.

Flotation is still in the empirical stage of development. Its success in one place is no criterion of the possible results at another. Its usefulness must stilll be determined wholly by experiment, varying the conditions as to oil, acid, temperature and combinations of these elements. But enough has already been done to show that it is a tremendous factor in ore treatment and that opportunity still awaits the investigator. When the horizon of the flotation process is happily clear of the clouds of legal patent litigation, progress should be more rapid and knowledge more widely disseminated.

The War and American Iron Trade

The European conflict has exerted a very slight influence upon the general course of the iron trade of the United States. The result is quite opposite to the expectations entertained in many quarters last August, when predictions were made of a rapidly expanding export trade, or quite contrary expectations entertained in other quarters in September and October, that business in the United States would be so paralyzed that there would be no domestic demand. Indeed, the whole course of events has been to illustrate in striking manner the unwisdom of making predictions when one is not acquainted with the circumstances.

Last August the view was very commonly expressed that here was the golden opportunity for the United States to build up a large export trade in iron and steel. It was unfortunate that we had not captured the trade already, but here was the opportunity to make up for lost time. The experience of only a few months has shown that if the United States had had a large export trade it would have suffered more severely than it did, for in the past few months the total demand for iron and steel among all the non-producing countries has been but a small fraction, probably less than one-quarter of what it was before the war. With Germany, Belgium, and France practically out of the competition, England's iron and steel exports have decreased by about 40 per cent, and the exports of the United States by about 20 per cent, even though in the case of the United States the exports have been swelled somewhat by demand for war material.

The immediate effect of the war was a stringent curtailment of iron and steel demand in the United States, but the demand in the past two or three months has been decidedly better and if the current demand is continued for two or three months longer the domestic demand in the United States for the full period since the war started will be approximately as large—or as small—as it was in the corresponding period before the inception of the war. The American iron trade was already in a state of almost acute depression.

In one respect there is still the possibility of the war having an acutely unfavorable influence upon the American steel trade, this possibility arising from the ferromanganese situation. Several months ago England placed an embargo upon the exportation of ferromanganese, subject to certain limitations which it was supposed would be easily met. American steel manufacturers were asked to sign an agreement that if they should receive English ferromanganese they would not export steel to certain designated countries, but the concerns that signed the agreement are still awaiting shipments. They have lately been approached with a fresh proposition of "marrying contracts" by purchasing additional ferromanganese at $68, in return for which they will be furnished equal tonnages of the alloy on their old contracts, made at from $35 to $38. The dollar looms so large in the negotiations that there now seems little doubt but that American steel makers will be able to secure ferromanganese when they are ready to pay the price.

There is another question, of magnesite for basic open-hearth furnace use, hitherto imported from Austria, but no serious apprehensions are entertained on that score. Altogether, the American iron and steel industry has suffered wonderfully little dislocation as to its raw materials and supplies from the European war, and there is much cause for congratulation that it proves to be so almost completely self-contained.

Taking Care of the Human Element

The passing from "first aid" to "safety first" is typical of the increasing attention now being paid by mining and metallurgical companies to the welfare of the human element in their operations. Just as they are now seeking to prevent accidents and avoid injuries by anticipating their possible occurrence through preventive measures, rather than offering remedial aid after accidents have happened, so also are they forestalling dissatisfaction and eliminating labor troubles by administering to the social welfare of their employees.

Seldom has any humane movement found such ready and world-wide acceptance as has been accorded to "safety first." Following less rapidly in its wake has come the less pretentious but equally important welfare movement for better sociological conditions. Perhaps the sequence is natural. Physical injury or fatal accident obtrudes itself on our attention, and its cost is definite and tangible. Social malaise and discontent cannot be expressed mathematically; and because it makes a less broad and striking appeal to human sympathy, its ill effects on industry have not been so apparent.

The good work of the pioneers in welfare work, however, has sharpened the perception of the great majority of large operators. Consideration for the human element, wherever it has been conscientiously observed, has been shown to yield tangible results in continuous and faithful service and efficient performance of duty. It has created the spirit of pride and loyalty so essential to the maintenance of effective organization, so that instances are not lacking where contented employees have been deaf to the arguments of unwise agitators. In fact, it has been apparent that by anticipating the welfare of employees, stimulating and directing their mental and social activities, prudent companies have forestalled dissention and avoided labor troubles.

The welfare work of the Homestake company in South Dakota is a conspicuous example. Under the direction of the late Thomas J. Grier, this company has shown commendable interest in the life and activities of its employees. Among the institutions established by the company is the hospital, the service of which is free to employees and their dependents. One thousand dollars monthly is contributed to an aid fund, to which the 2500 employees add one dollar each per month. This fund provides accident, sick and death benefits. For the wholesome amusement and recreation of employees, a large hall was erected by the company at a cost of $300,000. This contains also the Hearst free library.

Co-operation between industrial companies and the Y. M. C. A., which has been so effective in railroad work,

has been of benefit to mining companies. By agreement with this organization, companies are enabled to provide a social center for employees and their families, affording a place to spend time profitably and away from vicious influences. Such centers ultimately supply all the social needs of the community, as well as affording educational facilities. The Bunker Hill & Sullivan company has established at Kellogg, Idaho, an industrial Y. M. C. A., erecting a building at a cost of $35,000 and contributing $1500 annually to its support. Members pay an annual fee as in similar institutions elsewhere. This center serves at once as a social club, a meeting place for the labor organization and a night school. It is equipped with gymnasium and baths, billiard and game rooms, bowling alleys and public library. That it warrants support and has contributed materially to the welfare of employees, is the testimony of company officials.

Examples could be multiplied. The Copper Queen company in Arizona administers an employees' benefit fund to which it makes an annual contribution of $7500. This voluntary association of employer and employees has been found useful in spite of the adoption in Arizona of a compulsory workmen's compensation law. The Hollinger company at Porcupine adopted over a year ago a system of "loyal service" bonuses to day-wage employees without distinction save as to term of service. In 1914 this bonus amounted to nearly $12,000. It is based on a graduated scale of remuneration according to the term of employment. Men in service for over a year receive a bonus of fifteen cents per day; over two years thirty cents and over three years forty-five cents. At most of the large mines and metallurgical works that have come into existence during the last few years, some sort of provision has been made for the welfare and prosperity of the employees. In most cases the isolation of mine, mill or smelter has made necessary as well as advisable, the maintenance of clubs, places of recreation, model and sanitary homes, and participation in various kinds of benefits.

The Pyrophoric Alloy Decision

The final decision in the pyrophoric alloy litigation, as rendered by the United States Circuit Court of Appeals and printed elsewhere in this issue, is of considerable importance to the chemical industries, and particularly to those manufacturing alloys, both because of the chemical questions which it settles and the legal doubts which it terminates.

Considering the latter point first, the claim of the Welsbach patent involved in the litigation was for a pyrophoric alloy containing cerium alloyed with iron, while the specification mentioned nickel and cobalt as alloying metals, and also spoke of using iron or its equivalent, in making the alloy. The legal question was as to whether the claim of the patent, naming specifically only iron, was competent to cover any other alloying metal or metals; or, generalizing the question, as to whether a claim covers more than it specifically names, and may be extended to their fair equivalents. On this point the court rules that the patent being a pioneer invention is entitled to a liberal application of the doctrine of equivalents, which does not confine a patentee to equivalents which he has expressly referred to, but allows him any other fair equivalents unless he has himself restricted his claim by some statements in his specification. The specification of the Welsbach patent did indeed state that one of the metals in the alloy must be a rare-earth metal, among which metals cerium was relied on as essential to the composition of the alloy, thus restricting the claim on the cerium side; but the specification placed no restriction upon the other constituent, the iron side of the alloy, other than to specify that it must be a non-rare-earth metal; that is, not be a metal of the rare-earth class. This negative restriction led the court to the conclusion that each and every metal not of the rare-earth class must be considered as a fair equivalent for the iron in the Welsbach alloy, as long as it acts in a similar manner when alloyed with cerium. This extension of the field of a claim of a basic patent to cover all fair functional equivalents, even when not specifically named, and even when the claim does not speak of equivalents, is the first important point of the decision.

The second point, the chemical question at issue, was as to whether the term "equivalent" should mean, in the case of this alloy, as concerned the term "iron or its equivalent" in the specification, an element chemically related to or chemically equivalent to the iron, or should connote equivalency of function, or equivalency of result when used in the alloy. The respondent had strenuously urged that the equivalency in question must be regarded as chemical equivalency, and the metals replacing iron be limited to the metals associated with iron in the periodic system, such as nickel, cobalt and possibly manganese. The complainant, however, urged that such chemical equivalency had no meaning in the field of alloys and was absolutely without certainty or value in determining equivalency in producing a given desired result or property of an alloy. This position and principle were accepted without reserve by the court, which ruled that the equivalency of other metals with iron is to be found not in their chemical structure, but in their functional efficiency when combined with cerium in a metallic alloy. If this ruling is generalized it means that in an alloy, or in fact any chemical compound, protected by a patent, the "equivalent" of any claimed ingredient of the same is another element which acts functionally and with efficiency to create the same valuable property of the product, to an industrially useful degree. Such a functionally equivalent element may or may not be chemically related to it, or chemically in the same family of elements; whether it is or not is not the determining factor in considering equivalency in the sense of patent law. The law considers only functional efficiency; that is, capability, of acting to a useful extent, to produce the same result.

Owners of chemical and metallurgical patents and prospective applicants for the same should mark, learn and inwardly digest this interesting decision, because of its fundamental bearing upon the scope and meaning of "equivalents" in this class of patents.

Readers' Views and Comments

The Action of Fluorspar on Basic Open-Hearth Slags

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your issue of January, Mr. W. S. Hamilton proposes a theory to explain the great effect additions of fluorspar have upon the fluidity of basic open-hearth slags. There is no necessity of resorting to speculation, as the research of Karandief, published in the *Zeitschrift für Anorganische Chemie*, 1910, LXVIII, 188, has shown that $CaSiO_3$, melting at 1501 deg. C., forms an eutectic, with 38.2 per cent CaF_2, which freezes at 1130 deg. C.

H. O. HOFMAN.

Institute of Technology,
Boston, Mass.

Examination of Fire Bricks

To the Editor of Metallurgical & Chemical Engineering.

Sir:—I feel that a comment might be in order on the determination of titanium, as referred to under the title "An Examination of Fire Bricks," by W. Hamilton Patterson, in your February issue.

A procedure that I have found to give excellent results, with comparative ease of operation, is modelled largely after the method described by W. F. Hillebrand in Bulletin No. 422, U. S. G. S. The weight of silica previously obtained is corrected for the total residue, after treating with hydrofluoric and sulphuric acid. The precipitate containing aluminium, iron, etc., is then weighed in the crucible still containing this residue. Two or three grams of potassium pyrosulphate are then added and the alumina precipitate is dissolved in the fusion.

The melt is dissolved in dilute sulphuric, and any silica which has come down with the alumina remains insoluble. This should be weighed and added to the previously found weight of silica.

Care should be taken not to use too much heat in dissolving the melt, as titanium is sometimes precipitated if present in large quantities. The solution may then be split into two portions, determining iron in one and titanium in the other; or, if the iron is determined by zinc reduction and permanganate titration, titanium may be determined in the solution after this titration.

This method takes care, almost automatically, of the possible impurity of either the silica or alumina precipitate and insures the presence of all of the titanium in the sulphuric acid solution, whether or not any of it has been carried down previously with the silica.

J. S. BECKETT.

Cranford, N. J.

Fused Silica Dishes for the Concentration of Sulphuric Acid

To the Editor of Metallurgical & Chemical Engineering:

Sir:—In your January issue there is an article by Mr. William Mason on the concentration of sulphuric acid in cascade-type plants using fused silica dishes.

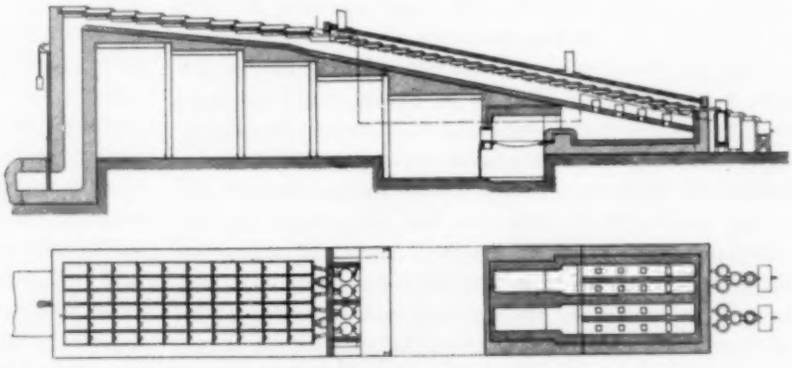
The description of the concentrator and the conclusions which are drawn are not applicable to the standard type of plant in general use, and as the production of concentrated sulphuric acid either from chamber acid or by-product acid, resulting from nitrating processes, petroleum treatment, etc., is of considerable interest at the present time, I would request the courtesy of space in which to outline the history and present status of fused-silica-dish-type concentrators.

The genesis of continuous cascade concentrators is undoubtedly the continuous glass retort system patented by Henry Chance in 1871. This system, which was in extensive use in England for many years, consisted of four or more glass retorts arranged in cascade, over a gas or coal fired furnace. The retorts were provided with glass connections, so that the weak acid fed into the top retort could flow through the other retorts, meanwhile undergoing gradual concentration. The acid drawn off from the last retort was led into a cooler, and thence into storage tanks or carboys.

The breakage of retorts was a serious figure in the operating costs, but the system survived owing to its low installation cost compared with platinum.

Attempts were made about 1887 to replace the glass retorts with porcelain, but the porcelain retorts were costly and gave no better results.

The next development came in 1889 when Négrier built a furnace, using porcelain dishes in place of the retorts, and a fume chamber of acid-proof brick over the dishes in place of the top of the retort and its connecting pipe. The Négrier furnaces were of small ca-



PLANT FOR CONCENTRATION OF SULPHURIC ACID

pacity and were superseded about 1900 by the Benker and Hartman system which made use of forty-eight porcelain dishes combined with a set of lead pans to utilize the waste heat and incidentally to carry the concentration from 50 deg. Beaume to 58 deg. Beaume.

The Benker and Hartman system gave fairly good results, but the breakage of porcelain dishes was a frequent cause of trouble, while the fuel efficiency was lower than other types of concentrator which came into use about the year 1906.

With the invention of vitreosil (fused silica) in 1906, and its development toward apparatus of commercial size in 1907, the cascade concentrator system took on a new lease of life, so that at the present time there are more vitreosil units in use throughout the world than any other type of concentrator.

The introduction of vitreosil dishes removed the two most serious faults of the porcelain concentrators, excessive breakage and low fuel economy, and enabled the design to be improved by substituting a single fire in place of the three used on the Benker-Hartman plants.

The breakage of porcelain dishes was caused through uneven heating or the slowing down of the feed and chilling of the dish when the feed was turned on ful

again. By reason of its low coefficient of expansion (0.54×10^{-6} or one-sixth that of porcelain) vitreosil dishes do not break through temperature changes no matter how severe, as is well evidenced by the usual lecture-room experiment of plunging a white-hot vitreosil crucible into cold water without breakage occurring.

Occasionally in the operation of vitreosil concentrators, the feed has been accidently shut off, the acid boiled out of the dishes, and then the full feed turned on again into the red-hot dishes without a dish being cracked.

This resistance to temperature changes permitted the vitreosil dishes to be directly exposed to the fire gases in open seatings, instead of being protected with 2-in. fireclay slabs, which, of course, gave a greatly increased fuel economy.

The position of the firebox and the type of furnace has been a source of continual experiment and the plus pressure furnace referred to by Mr. Mason has been tried out by two factories only, as it was not found possible to get the temperature regulated over the whole length of the concentrator.

Natural-draft furnaces burning soft coal have given the best results and are in general use. Furnaces burning fuel oil and natural gas are also used, but the construction is similar to the soft-coal furnaces.

The illustration on page 136 shows the general outline of a unit to produce 20,000 lb. 66 deg. Beaume per twenty-four hours from 50 deg. Beaume H_2SO_4 and shows clearly the furnace position and arrangement of firing flues. This unit contains 100 dishes (12¼ in.) and sixty pans (24 in. by 12 in.) used in place of lead preheating pans. All the pans and dishes, excepting the last three in each row at the exit end of the plant, are supported in open seatings and are directly exposed to the fire gases. The last three dishes have closed seatings, as experience has shown that with open seatings at this point, the acid boils strongly, with loss of SO_3 and spurting of liquid on to the seating. The breakage of lower basins referred to by Mr. Mason was in all probability due to the use of open seatings. The acid spurted over would come into contact with the seating and the asbestos rope gasket, and gradually form a solid mass. The contraction of the seating with a slight cooling of the plant, would break the basin unless it was free to rise and fall on its gasket, as the relative coefficients are as 1 is to 14.

Units such as shown in the cut will concentrate 50 deg. Beaume H_2SO_4 to 66 deg. Beaume, with an average fuel consumption of 17 per cent of 13,000 B.t.u. soft coal, consumption being based on the weight of finished acid. The breakage of dishes in fifteen factories for which accurate records are available, has always been under 5 per cent per annum from all causes, while the failure of preheater pans is less than 1 per cent per annum.

The first silica-basin concentrator was installed in 1907 and at the time of writing upward of 500 complete units are in use throughout the world, thus indicating the value of the vitreosil dish system.

A considerable proportion of these plants handle recovered acid containing traces of nitric or organic acids, as vitreosil is attacked only by hydrofluoric acid.

Within the last year several units have been put up for the continuous concentration of solutions, either containing free acid or substances which will attack iron, lead, etc., and providing the solution is run off before crystallization takes place, excellent results can be obtained.

ALBERT E. MARSHALL,
Manager, The Thermal Syndicate, Ltd.
New York City.

Quantitative Blowpipe Analysis

To the Editor of Metallurgical & Chemical Engineering:

Sir:—Returning from a two months' trip to Panama and the West Indies, my attention has been attracted by the two well-written and instructive articles on the above subject by Mr. Fischer, in your November and December issues, 1914. Mr. Fischer does not exaggerate unduly the usefulness of these aids to the prospector, but he has exaggerated somewhat my personal contribution to the advance of this art. I refer particularly to being credited with devising the useful little scale of alloys of gold and silver. This was devised by my own instructor in the art, Dr. Victor Goldschmidt of the University of Heidelberg; my own contribution was merely the suggestion of a brass case with screw top to ensure safe carriage of the scale in the prospector's kit.

JOSEPH W. RICHARDS.
Lehigh University,
South Bethlehem, Pa.

"Limitations of the Electric Furnace in the Manufacture of Steel Castings"

To the Editor of Metallurgical & Chemical Engineering:

Sir:—On page 110 of your February issue Mr. G. Muntz, in the article of "Limitations of the Electric Furnace in the Manufacture of Steel Castings" refers to my article in *The Iron Age* of March 27, 1913, as one which contained statements which were the products of enthusiasm and at variance with actual facts. Not one word of evidence was given to substantiate this statement and no statement in my article was even mentioned.

Mr. Iver Rennerfelt, on page 582 of your September issue, quoted me correctly and gave the facts that are recognized by nearly all metallurgists. Those that know about the manufacture and casting of steel know that the Bessemer converter was a wonderful invention for cheapening the manufacture of steel and giving it a field of usefulness that it did not have before that time. No one argues that the Bessemer converter makes as good steel as the open-hearth furnace. Likewise no metallurgist claims that the open-hearth furnace makes as high-grade steel as the crucible or electric furnace in commercial quantities. Metallurgists also know that the converters, used in steel foundries, are modifications of the Bessemer process and cheapen the production of steel castings but do not improve their quality.

The most foolhardy foundrymen would not attempt to use the steel coming from a converter to cast the wheels, with hollow spokes and rims, which I illustrated in that article in *Iron Age*, and guarantee them to be absolutely free from blow holes. Wheels that were 24 inches in diameter were cast with walls but ⅛ of an inch thick and with ½-inch fillets where the spokes join the rims. Only ⅛ in. was allowed for finishing the face and sides of the rims and the hubs.

In that article I described, in detail, why such castings could not be made commercially from steels melted and refined in converters, or even in open-hearth furnaces, and yet Mr. Muntz did not mention even one of these, to say nothing of refuting them. Not being retained by any steel maker or furnace builder, I was free to express all the facts that my investigations presented. Anyone capable of appreciating it, should be enthusiastic over a fine piece of work. That is positively no argument against the facts I gave as to how these castings were made, or how they could and could not be made.

In the *American Machinist* of Dec. 13, 1908, I described and illustrated some steel castings made by the Flexilis Works in Germany that were even better than

these. An exhaust manifold for an automobile engine was cast by them in lots of 500. It was 22 inches long with a 1½-inch pipe. Its center was water jacketed with a ½-inch space and an outside diameter of 2¼ inches. All the walls were cast 3/16 of an inch thick and the flanges were given ⅛ of an inch finish. Steel cylinders 12 inches diameter and 18 inches long, with outside ribs, were cast with ¼-inch walls. All the fillets were ¼-inch and the finish on the cope end was but 3/16 of an inch. Many other castings of a similar nature were shown and they were all guaranteed to be entirely free from blow holes.

They would also cast them from any steels with any carbon content desired and also from any of the high-grade alloys.

This story was doubted and called enthusiasm by American foundrymen using converters and open-hearth furnaces until an American foundry, using crucible furnaces and the German methods, began to market a similar product. It would be suicide for any foundrymen to attempt to make steel castings to such specifications, at a commercial price, from converters or open-hearth steel. Blowing air through iron to reduce the carbon content to that of steel, as the converter does, cannot reduce the oxides, nor does it reduce the sulphur and prosphorus to as low percentages as will be found in steels coming from the crucible or electric furnaces.

Metallurgists that have not become commercialized will not claim that these and other impurities can be commercially reduced to as low percentages in converter steel as in those made in crucible, electric or even open-hearth furnaces.

I do not want to be misunderstood by the thought that I am condemning the converter entirely. Modified Bessemer converters, either of the Bradley Stoughton or Tropenas type, have been of great benefit to the steel casting industry and will continue to have a large field of usefulness. But when one tries to argue that they make better steel than the crucible or electric furnaces he expresses things that are at variance with the vast amount of data that have been compiled nnd published about steels in the past few years. Some very high-grade steels can be made in the open-hearth furnace by using three or more slags for purifying the metal and materials that act as scavengers, but this adds considerably to the cost and might make the steel more expensive than that which is made in electric or crucible furnaces. Likewise, more time and materials might be used to make converter steel of a higher grade than is now the case, but the impurities cannot be removed as thoroughly as by the processes used in other furnaces. Where cost is a big factor the converter becomes a very important tool, but when quality is the main consideration other furnaces give better results.

Detroit, Mich. E. F. LAKE.

Tube-Mill Tonnage Calculation

To the Editor of Metallurgical & Chemical Engineering:

SIR:—I was much interested in Mr. A. H. Jones' very complete discussion of my tube-mill tonnage formula, in your February issue. I should have pointed out in my original discussion in your January issue that any mesh can be used as the basis of the calculation; thus it can be based upon plus 28-mesh as Mr. Jones has done in his illustrative calculation.

I instanced minus 200-mesh, as to most millmen "per cent. minus 200" carries a distinct meaning; knowing the minus 200 one can reconstruct the approximate screen test of any normal ore, and no other size gives the same general information. The numerical expression for ratio of tube-mill tonnage to battery tonnage, based upon the plus 28-mesh from Mr. Jones' screen tests is:

$$\frac{T}{B} = \frac{d-a}{c-b} = \frac{0-41.8}{0-21.8} = 1.91$$

as he correctly calculates it. However, if his sampling and screen tests are accurate, the same formula applied to his minus 200-mesh should give the same ratio. The numerical expression based upon minus 200 in his screen tests is

$$\frac{T}{B} = \frac{d-a}{c-b} = \frac{72.3-21.2}{28.1-6.5} = 2.39$$

I have tabulated below Mr. Jones' screen tests with an added column giving the ratio of tube-mill tonnage to battery tonnage as calculated for each size of screen by my formula.

TABLE II FROM MR. A. H. JONES' DISCUSSION

Mesh	Battery Discharge Per Cent	Tube-Mill Feed Per Cent	Tube-Mill Discharge Per Cent	Dorr Overflow Per Cent	Ratio Tube-Mill Tonnage to Battery Tonnage $\frac{d-a}{c-b}$
	a	*b*	*c*	*d*	
10	10.3	5.4	....	....	1.91
14	10.0	5.2	....	....	1.92
20	10.2	5.3	....	....	1.91
28	11.3	5.9	....	....	1.92
35	7.7	4.9	1.0	....	1.97
48	7.4	6.5	3.1	....	2.09
65	5.6	8.1	6.5	....	3.50
100	6.0	20.0	20.0	1.0	....
150	6.6	24.4	28.6	12.5	1.40
200	4.0	7.8	12.7	14.2	2.08
—200	21.2	6.5	28.1	72.3	2.37
				Average	2.11

It will be noted that the individual calculations do not check very well, and my experience has been that screen tests from samples taken over a period of only a few hours are very apt to be misleading. Segregation is the salient feature of the tube-mill-classifier closed circuit, and a very slight adjustment of the batteries may introduce irregularities which take hours to become readjusted. Samples taken carefully over a considerable period of time will give approximately the same calculated ratio of tube-mill to battery tonnage for each mesh.

For this purpose, daily routine sampling is best, the samples being taken by the mill crew and the screening being done in the laboratory. One has a check on the accuracy of the work by applying the formula to each mesh.

I regret that I have not with me at this writing any screen test records. Certainly publication of a series of screen tests such as Mr. Jones gives, for a number of mills, would be a very valuable addition to technical literature and would throw an interesting light upon the milling of various ores.

Douglas, Ariz., Feb. 16, 1915. NOEL CUNNINGHAM.

The Western Metallurgical Field

Platinum Milling in Wyoming.

In our issue of February 1911, page 75, was described the concentration of platiniferous ore at the Rambler mine in Wyoming. The work as then described was continued for some time, but the mill was subsequently closed and a period of inactivity followed. Several months ago, however, work was renewed by the Platinum Mining & Milling Co., an organization of stockholders under the management of Mr. Julius Thielman, which leased the property. For the past two months the 50-ton mill has been in operation, concentrating the dump ore, and the first shipment of concentrate was to have been made during February. According to Mr. Robert A. Marr, metallurgist for the company, the concentrate contains platinum, palladium, iridium,

osmium, gold, silver and copper. At the rate of milling, the dump contains sufficient ore for one year's operation, and there is still ore in the mine which will be kept in reserve.

Several interesting changes have been made in the milling system since the work was described four years ago. Chief among these is the use of a Peck centrifugal concentrator. This machine is of a different type than the one used experimentally at Anaconda. The latter was of the vertical type, while the one under consideration is horizontal. The ore is ground to 60-mesh in a Hardinge pebble mill working in closed circuit with a drag classifier, the oversize being returned for regrinding. Following the drag classifier is a 60-mesh screen which finally limits the size of the pulp particles. Its principle function, however, is to remove wood pulp or other foreign matter that would interfere with the operation of the concentrator. The Peck horizontal-type centrifugal concentrator is the only one of its kind in use, and handles the entire product of the crushing department, producing concentrate and tailing. In order to insure a pulp of uniform density for the concentrator feed, the ground ore is kept in agitation in a tank fitted with paddles.

In the early operation of the mill considerable difficulty was encountered from the acidity of the ore. Some of the copper occurs as sulphate, and there are other soluble forms. The mill water, becoming impregnated with acid copper salts, corroded screens and metal work throughout the mill, causing delays and increasing cost of operation. In order to overcome this difficulty the present management is adding from five to six pounds of lime per ton of ore at the crusher, so that the mill water is alkaline. This corrects not only the acidity of the ore, but also of the mine water which is now being used for milling.

Milling Results at Magma Copper Mine.

The Magma Copper Company, developing a large low-grade copper mine in Arizona, has had in operation at the mine a mill of 150 tons daily capacity for the purpose of testing milling methods. A combination of water concentration and oil flotation is in use. The recovery of copper, including ore sorted by hand, has averaged over 85%. During the year ended December 31, 1914, shipments of picked ore and concentrates amounted to 5474 tons, averaging $1.90 gold and 22 oz. silver per ton, and 20% copper. The product has been hauled by teams about 32 miles to Florence, Arizona; but at present a narrow gage railroad is under construction from the mine to Webster, a point on the Arizona Eastern Railroad, about 31 miles from the property.

Quicksilver in Nevada.

The Nevada Cinnabar company has recently begun the treatment of mercury sulphide ore at its mine at Ione, Nevada. The main feature of the plant is a 50-ton Scott continuous roasting furnace, with supplementary equipment in the form of condensers and refinery. The ore is crushed to 1½ in., dried in a rotary dryer and then charged in the furnace. The temperature is maintained at about 1000°F. Mercury distills and passes from the furnace through side ports to a dust chamber and thence to the condensers. Of the latter there are eight independent sets of two chambers each, connected by terra cotta pipes. The condensers are cleaned through doors suitably arranged. About 30% of the mercury recovered runs from the condensers, but the remaining 70% is retained by heavy carbonaceous matter or soot. The entire product from the condensers is moistened and placed in a pan that is heated to a low temperature by means of steam. The mixture is then worked with a hoe which causes the mercury to coalesce and run free from the soot. A rotary machine designed to perform this operation mechanically is soon to be installed. The condensed product from the last few sets of condensers contains considerable moisture. In the treatment of this product, ashes, lime or other dry alkaline material is added in order to reduce the moisture content and at the same time cut the greasy film that prevents the globules of mercury from running together. Altogether about 90% of the mercury condensed is recovered, and the balance together with the soot is recharged to the furnace in small quantities. As the plant has been in operation only a short time, and no complete clean-up has ben made, it is impossible to indicate the percentage of extraction.

Federal Mining Experiment Stations.

A bill introduced in the House of Representatives by Congressman Foster, chairman of the House Committee on Mines and Mining, and known as House Bill 15869, has been passed by that body. It provides for the establishment of ten mining experiment stations and fifteen mine safety stations in the several important mining districts of the United States and Alaska, under the direction of the Bureau of Mines. The function of the mining experiment station is to investigate conditions and suggest improvements in the mining industry, preventing unnecessary waste of resources, and generally contributing to the advancement of the industry. No appropriation is mentioned, but it is understood that $750,000 will be required to make the act effective. Provision is made, however, for accepting "lands, buildings or other contributions from the several States offering to co-operate in carrying out the purposes of this Act." It now seems possible that the bill will be passed by Congress at this session. It would have been better if the sum of $750,000 could have been placed at the disposal of the Bureau of Mines without making it necessary to dissipate a considerable portion of the sum in the maintenance of so many stations; but it appears politically necessary to accept these conditions in order to make an entering wedge for some federal support to mining.

Company Reports

The Wellington Mines Co., operating mine and mill at Breckenridge, Colo., makes the following report for the year ended November 30, 1914. Developed ore amounts to from 45,000 to 50,000 tons, containing from 4 to 5% lead and 17 to 18% zinc. The wet concentrating mill was idle during six months of the year, and was thoroughly overhauled, the capacity being increased to 125 tons daily. The magnetic mill also was closed during April for repairs. A Hardinge ball mill and another magnetic separator have been added to the equipment, giving a better recovery of both lead and zinc. The wet concentrating mill treated 17,430 tons of ore, averaging 17.4% zince and 4.98% lead, producing 1106 tons of concentrates assaying 34.8% lead (dry), and 9145 tons of middlings assaying 24.13% zinc, 2.46% lead and 27% iron. The magnetic mill treated 8172 tons of this middling, producing 3657 tons of concentrates assaying 46.14% zinc and 83.9 tons of lead concentrates assaying 64.1% lead. In addition to this, the magnetic mill treated during the first five months of the year 6820 tons of middlings assaying 18.62% zinc and 3.44% lead, producing 2028 tons of 47.75% zinc concentrates and 161 tons of 65.2% lead concentrates. The tailing from the magnetic mill carries 53% iron and some gold, silver and lead, but it cannot be marketed on account of high freight rates.

Nevada Consolidated Copper Co. has issued its

fourth quarterly report showing the production for the year 1914.

The copper output during the four quarters was as follows: 15,597,592 lb; 14,322,807; 11,258,421; 8,065,-236. During the fourth quarter the property was operated on a basis of 50% normal capacity. The tonnage treated was 416,825 and the grade 1.54% copper. The cost of copper, crediting miscellaneous earnings, was 8.42 cents per pound. After payment of the 20th dividend, there was a deficit for the quarter of $378,949. The physical assets of the Steptoe Valley Smelting & Mining Co. having been acquired by Nevada Consolidated in August 1914, the former was legally dissolved in November 1914.

Chino Copper Company's report for the fourth quarter of 1914 shows a production of 8,935,585 pounds of copper, as compared with 17,288,678 pounds in the first quarter. The average daily tonnage treated in the fourth quarter was 3774 as against 6469 tons in the first quarter. The total copper production for the year 1914, including copper contained in crude ore shipped, was 56,841,977 pounds. The average grade of ore treated in the fourth quarter was 1.8612% copper as against 2.1653% for the third quarter. The average extraction was 69.14%, as against 68.04% for the previous quarter. The ratio of concentration was 19.82 to 1. The cost per pound of copper, without allowing credits from other sources, was 8.14 cents. Credit for gold amounted to 0.12 cents per pound. With all miscellaneous earnings credited, the cost per pound was 7.71 cents.

Ray Consolidated Copper Co. shows a production of 9,563,113 pounds of copper during the fourth quarter of 1914, as compared with 17,707,374 pounds in the first quarter. The ore milled during the quarter amounted to 402,917 tons, averaging 1.74% copper. Average mill recovery was 68.2%. Milling costs were 54.56 cents per ton, compared with 45.85 cents for the previous quarter, the increase being due to the decreased tonnage. Average coarse crushing cost was 2.666 cents per ton, and mining cost 49.722 cents. Net cost of copper was 8.748 cents per pound; crediting miscellaneous income it was 8.645 cents.

Utah Copper Company's fourth quarterly report for 1914 shows a production of 20,229,012 pounds of copper, as compared with 40,017,562 pounds in the second quarter. The gross production for 1914 was 121,779,-401 pounds; for 1913, 119,939,809 pounds. The quantity of ore milled in the fourth quarter was 1,035,303 tons, all at the Magna plant. The average grade of the ore was 1.5062% copper. Extraction was only 64.86%, as compared with 68.13% in the previous quarter. The reduction was due to carbonate of copper in the ore. The average cost of copper for the quarter was 7.731 cents per pound, crediting miscellaneous income it was 6.688 cents. The financial statement shows a deficit for the fourth quarter of $142,293.

The Wolverine Copper Mining Co., Michigan, gives the following data on operation in the annual report for the year ended June 30, 1914. Ore stamped amounted to 182,127 tons, from which 4,606,015 pounds of mineral was recovered, yielding 3,435,459 pounds of refined copper. Cost per ton of ore stamped, $1.92; cost per pound of refined copper at the mine, 9.85 cents; total cost refined copper, 11.3 cents per pound.

The annual report of the **Coniagas Mines Ltd.,** Cobalt, Canada, for the year ended October 31, 1914, states that the year was not so profitable as the preceding three years, owing to the low price for silver, the diminishing output of high-grade ore and the dislocation of business due to the war. No valuable discoveries were made on outside claims staked by the company. The annual bonus to employes at Christmas time amounted to 4% of their annual earnings, or $8,682. The concentrating mill treated 54,522 tons of ore, averaging 24 oz. silver per ton, at the rate of 2.93 tons per stamp. High-grade concentrates shipped amounted to 496.4 tons, averaging 2030 oz. silver per ton; low-grade slime amounted to 251.8 tons, averaging 151 oz. Mine ore shipped amounted to 493 tons averaging 2944 oz. Sand tailings from the mill averaged 3.18 oz. silver per ton, and slime tailings 6.66 oz. It is estimated that the ore reserves contain 14,880,000 oz. silver.

From the report of the **Mount Morgan Gold Mining Co.,** Queensland, Australia, for the half-year ended November 29, 1914, the following data are taken. The concentrator handled 31,274 tons, recovering 87.4% of the copper and 77.5% of the gold. The smelter treated 179,939 tons. The production was 4593 tons of refined copper and 58,309 oz. gold. The new smelting furnaces were started in July, two being in operation and one held in reserve. Some difficulty has been experienced in handling flotation concentrates, but experiments have indicated a solution of the problem, which, however, is not stated in the report.

The annual report of the **Hollinger Gold Mines, Ltd.,** of Ontario, Canada, shows that $2,688,354 was recovered from milling 208,936 tons of ore of an average value of $13.67 per ton. The gross profits amounted to $1,786,-680. Dividends paid amounted to $1,170,000. The mill was in operation 92.2% of possible running time, and handled an average of 633 tons per 24 hours of running time. The stamp duty was 13.30 tons per 24 hours. Chemical consumption per ton of ore: cyanide, 0.525 lb.; lime, 1.557 lb.; zinc, 0.532 lb.; acid, 0.216 lb.; lead acetate, 0.0031 lb. Average value of pregnant solution, $5.698. During the year there was stacked for retreatment 6062 tons of concentrates of an average value of $8.85 per ton. The rapid development of the property has necessitated enlarging the mill, and it is expected that 100 stamps will be dropping by the middle of March 1915. Continuous decantation has been adopted for a considerable tonnage of ore treated. Distribution of milling cost is as follows, based on total tonnage treated and including 2910 tons of ore milled for the Acme company. If based on Hollinger ore only, 208,936 tons, the cost is $1.22 per ton.

Account	Per ton
General milling charges	$0.054
Superintendence	.047
Tailings disposal	.018
Lighting	.011
Heating	.039
Shoveling in bins	.012
Crushing	.079
Conveying	.034
Stamping	.160
Classification and tube-milling	.188
Concentration	.062
Handling concentrates	.007
Treating concentrates	.032
Handling pulp	.040
Thickening	.014
Continuous decantation	.031
Filtration	.103
Neutralizing	.012
Clarifying and precipitation	.063
Refining	.059
Pumping solutions	.021
Cyanide	.083
Cleaning mill	.019
Alterations	.034
Assaying	.015
	$1.237

Present Tendencies in Copper Metallurgy

BY E. P. MATHEWSON
General Manager, Anaconda Copper Mining Company

Finer Grinding in Ore Dressing

In ore dressing, the flotation process is finding a vast field in sulphide copper ores, particularly those in which the sulphide minerals are finely disseminated. Numerous processes, so-called, are being placed on the market and a great variety of flotation machines. A number of these machines have given marvellous results, giving a tailing as low as 0.08 per cent copper, this having been obtained in continuous runs lasting for several weeks and representing thousands of tons of material. Strange to say what was considered impossible a few years ago, namely, the concentration of slimes by flotation processes, is now accomplished without any difficulty whatever.

The wonderful improvements in the reverberatory smelting of copper ores, to be mentioned below, have changed the ideas of millmen, so that coarse jigging will soon be abandoned, and nothing will be jigged coarser than ⅜ of an inch size.

The material for flotation seems to concentrate better in proportion to the fineness to which it is ground. In many mills 60-mesh material is the coarsest that is sent to the flotation machines.

In roasting concentrates, the furnace of the McDougal type seems to have the preference. There are several styles of these furnaces on the market, and all seem to be giving good results.

Reverberatories Superseding Blast Furnaces

The introduction of oil fuel, followed a few years ago by the successful use of pulverized coal on reverberatory furnaces smelting roasted copper concentrates, has revolutionized reverberatory construction and practice. The latest furnaces are 25 ft. by 144 ft. inside dimensions and have a capacity of from 700 to 800 tons daily, with a fuel ratio of better than 7 to 1. A still larger furnace is now in course of construction that will measure 175 ft. by 25 ft. inside. This furnace is for the purpose of treating hot converter slags with raw copper concentrates in order to recover the copper in the slags and to make a slag clean enough to be thrown away. This furnace is estimated to have a capacity of over 1100 tons daily. Of course a greater part of the charge will be molten slag.

The fuel economies from the use of pulverized coal are astonishing. With a grate-fired furnace, and a similar furnace using the same coal in pulverized form, the fuel ration in the first case will be 4¼ to 1; and in the latter case, 7 to 1. The tonnage smelted by the pulverized fuel furnace is practically double that smelted by the grate-fired furnace. These economies will result in the relegation of the blast furnace (in a great many plants) to the smelting of extremely refractory ores, or it will cause their abandonment altogether, as the reverberatory furnace in most localities will be able to do the work at about 75 per cent of the cost of blast-furnace operation. Of course, there are some ores that it will be cheaper to treat in blast furnaces.

In blast-furnace practice the tendency is to enlarge the furnaces, and the types of furnace that may now be had give entire satisfaction, certain improvements having been introduced in recent years so that while the length of the furnace may be increased indefinitely, the size of the unit is not increased at all, as one part of the furnace may shut down for repairs while the rest of the same furnace may be kept in operation. The largest furnace at present in operation is 87 ft. long and 56 in. wide, inside measurements at the tuyeres. This furnace has smelted in 24 hours over 3300 tons of charge.

Basic-Lined Converting

In converting, the basic-lined converter is rapidly displacing the acid-lined shell, and the size of the converter is being increased proportionately to the capacity of the plant, up to a maximum of the vertical (or Great Falls) type of converter, of 20 ft. inside diameter. The vertical type of converter is preferred at most of the large smelters; the objection to the horizontal cylindrical type being the necessity for the numerous openings, in the larger converters, for the introduction of silicious material and the difficulty of getting uniform temperature, and agitation of the charge throughout the converter. In the 20-ft. vertical Great Falls type of converter there is no difficulty whatever in these matters. All new converters are operated electrically instead of hydraulically.

Another branch of copper metallurgy that is receiving a great deal of attention at present is hydrometallurgy, or leaching. Enormous plants are being constructed in various parts of the world to handle low-grade ores that are oxidized, or partly oxidized; and also to recover copper from old tailing dumps in which the copper has become oxidized.

Losses Minimized

Great attention is being paid to the recovery of valuable metals from fumes and from flue dust, and a modern plant must be equipped with apparatus for saving these metals. The Cottrell electrical precipitation apparatus seems to be the most suitable for copper-smelting operations; although with some ores, particularly those carrying zinc, the bag-house has been successfully introduced for this purpose, following the practice of lead metallurgists.

The economical handling of materials to and from the furnace is now brought nearly to perfection.

In conclusion the modern tendencies in copper metallurgy can be summed up in these words: Increased recovery in ore dressing: increased recovery of metals formerly lost in smoke and fume: reduced cost of operations, due to the introduction of larger smelting units and mechanical means of handling materials to and from furnaces: the introduction of pulverized coal as fuel for reverberatory smelting furnaces.

Anaconda, Mont.

Magnesium

The Aviation Materials Corporation has been incorporated under the laws of New York State to engage in the business of manufacturing metallic magnesium.

The corporation will operate under the patents of George O. Seward and F. von Kügelgen, the process having been developed by them at the Virginia plant of the Virginia Electrolytic Company.

Mr. George O. Seward, 99 Cedar street, New York City, is the president and general manager of the Aviation Materials Company. Work has been started on a plant to turn out ten tons of metallic magnesium monthly and the corporation expects to have the metal for sale inside of three months.

The **Joseph Dixon Crucible Company** of Jersey City, N. J., has just issued a new edition of the booklet "Dixon's Graphite Crucibles." In addition to a preface and the table of crucible sizes, information is furnished of steel melting crucibles, file crucibles, crucible covers, tilting furnace crucibles, retorts, bottom-pour crucibles, stirrers, skimmers, dippers and self-skimming crucibles. Some good advice is given in two pages entitled "For Oil Furnaces" and "General Hints" on the scalping of crucibles, use of fluxes and use of tongs. Foundry facings and a highly refractory cement for the repair of worn or cracked firebrick are also described.

Concentration by Crushing and Screening at the Vindicator Consolidated Mill

The new crushing and screening mill of the Vindicator Consolidated Gold Mining Company in the Cripple Creek district was put in operation Oct. 15, 1914. The object of the process employed is to increase the profit from the mine by treating the waste ore that formerly went to the dump. It is characteristic of many Cripple Creek ores that mechanical enrichment can be produced by simply crushing and screening, saving the finer and rejecting the coarser portions. This affords a simple method of concentration that will yield profitable smelting products from otherwise waste rock. The ultimate profit per ton is not great, but amounts to a considerable sum on a large daily tonnage. The cost of a mill is small compared with that of a concentrating and cyaniding mill such as is adapted to Cripple Creek ores, and the process probably can be applied to ores of too low grade to be treated profitably by the more elaborate process.

The former practice at the Vindicator was to sort the mine ore, shipping the first-class product to smelters and washing the waste in order to recover fine rich mineral adhering to the surfaces of the rock. The extent of the sorting process and the quantity of ore rejected from run-of-mine product is indicated in the last annual report of the company, wherein it is shown that of 76,295 tons of crude ore hoisted, 26,343 tons of shipping ore was sorted, leaving roundly 50,000 tons of waste rock to be thrown on the dump. The problem at the Vindicator was to devise a profitable method of treating this ore-house waste, for the simple expedient of washing the waste and recovering fine mineral was not wholly satisfactory. Accordingly experiments were begun in 1913, under the direction of Mr. Edward S. Wiard, of Denver, to see what improvement could be made.

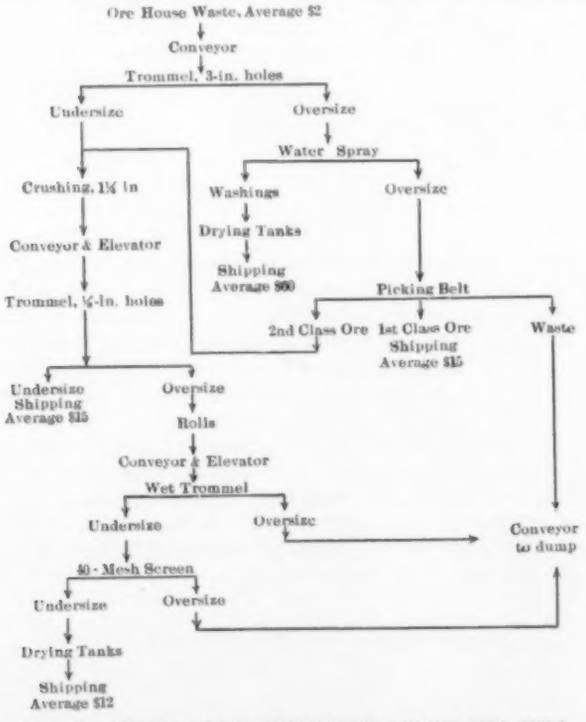


FIG. 1—FLOW SHEET VINDICATOR SCREENING MILL

Preliminary Tests

Early tests indicated that the waste was capable of enrichment by crushing and screening. Experiments by jigging and tabling also showed good results, but not sufficiently high to warrant the consideration of such a process. The complete testing work involved many experiments in crushing, sorting, screening and washing, with separate assays of the various products. From these tests data were obtained showing quantities and values, and affording a basis for intelligent design of a mill. The plant as finally built cost roundly $34,000, and is reported to be treating about 400 tons daily.



FIG. 2—VINDICATOR SCREENING MILL

The flow-sheet of the mill is given in Fig. 1, and a view of the plant in Fig. 2. The ore-house stands at the left of the mill in Fig. 1, being connected herewith by a conveyor that delivers waste rock from the picking-belt in the ore-house to a large trommel screen in the mill. The first section of the trommel screens out 3-in. rock and delivers it to the second-class ore bin. In the second section of the trommel the remaining rock receives a wash of water sprayed under 50 lb. pressure. The rich washings are delivered to settling tanks, and are shipped after drying. The trommel oversize is delivered onto a sorting-belt from which first-class shipping ore is easily picked by hand after the washing it has received. Second-class ore also is sorted and combined with the trommel undersize. The final waste from sorting falls onto a cross conveyor and is discharged to the dump.

The second-class ore is then crushed to 1¼-in. size and elevated to dry trommels fitted with ⅛-in. screen. The undersize of these trommels is a shipping product, and the oversize is retained for a second crushing in rolls to ⅜ in. The roll product is then washed in a wet trommel which serves merely as a scalping screen for the Bunker Hill 40-mesh screen which follows. The wet-trommel oversize is discarded, but the undersize is further screened on a Bunker Hill screen of 40-mesh, the oversize of which also is discarded. The undersize is a shipping product and is delivered to a settling tank and then dried. Thus the process comprises a preliminary wash, crushing in two stages with intermediate dry screening and final wet screening at ⅛ in., and 40-mesh, respectively. The values of the several concentrates are shown on the flow-sheet.

The arrangement of the plant is simple and convenient. The screens and picking-belt are placed in the top of the building, above bins and tanks which receive

the various products. All of the waste rock rejected from the picking-belt and screens is delivered to a common conveyor leading to the dump. The crusher and rolls are placed below their respective bins, and discharge their products onto conveyors leading to the two elevators that serve the dry and wet trommels.

The annual report of the company, dated Jan. 1, 1915, states that the new mill "has not been in operation at this time long enough to make any positive assertions, but the indications are that it will prove to be a very profitable investment." Judging from the care taken in the preliminary tests, the mill should add to the general profit of the company.

The Radium Situation

BY WARREN F. BLEECKER

The Standard Chemical Company of Pittsburgh was the first company with sound finances to seriously enter the radium business in the United States. Indeed there were scientific men in our own state, who, during the year in which this company was founded, seriously doubted that radium occurred in carnotite ores in commercial quantities, if at all. There were, in this country, no men who could determine radium quantitatively with any degree of accuracy and there were no metallurgical engineers trained in the treatment of the ores.

This is the problem, among others, Mr. Flannery has had to face, and how well he has done it the record of the last year has shown. Being a man of tireless energy, remarkable foresight and business ability, and associated with some of the best capitalists of this rich eastern country, Mr. Flannery carefully laid the foundation of a permanent business, the first of its kind in this country and the largest of its kind in the entire world.

The first step was the obtaining of property both by outright purchase and by location according to the laws of the land. As is well known, the Standard Chemical Company obtains its supply of raw ore from the south-western part of Colorado. When this company first came into the field the country was practically a wilderness; miles of roads were built, streams were bridged, homes were erected and employment furnished to hundreds of men and teams, thousands of dollars were expended monthly in salaries, wages and supplies. The problems of mining and transportation in this district are as great and no greater than in any other district of like isolation and remoteness from settled centers and supply bases. I do not mean, of course, that the Standard Chemical Company discovered radium in Colorado or that the country had never been entered by civilized man any more than a certain government official meant that he had discovered radium by having his photograph taken at the mouth of one of our tunnels, although the newspaper reports so stated. I wish to point out, however, that the real pioneer work of the development of radium mining, in the Paradox region, was done by private capital and that more than one million dollars had been expended in mines and processes before any cognizance or recognition of the work was taken up by the government.

After the development of mines, the building of roads and of camps, finally came the shipping of large quantities of raw ore, then of almost unknown value, to Pittsburgh. Then came the erection of the plant in which the experimental work was to be done. Following this was a long siege of costly experimental work; the training of engineers and scientists in the reduction of the ores, quantitative determinations of the values therein, the refining of the crude material into marketable products and the building up of a selling organization.

Any one who is familiar with the pitfalls which are confronted at every step in the building of a large business, using known methods, and producing standard materials, will at once realize what it has meant to found an establishment with unknown raw materials, untried processes for treating them, and with no market demand for the products.

Radium itself, considered in the light of its weight in pounds and ounces only, is a metal of almost fabulous value. When it is seen that it may be necessary to treat 1 ton of ore to obtain 1 mg of radium, it will be seen that the metallurgist is removing one part of material which he can never see, feel, or recognize by any of his natural senses, from one billion parts of foreign matter. Further, this one part must not be lost although it is carried through a maze of chemical reactions, in expensive and sometimes fragile apparatus, until it is relatively pure and ready for refining. When it is further realized that the loss of one drop of liquid, under some conditions, would result in the loss of several hundred dollars worth of radium, some conception may be had of the difficulties involved in removing this element from the raw ore and its subsequent refinement.

During the last two years, certain persons have prevailed upon a branch of the national government to assist them in entering the radium business, not in competition with, but to the ultimate exclusion of, the producers now in the field. So far as the general public know, this is purely a government enterprise. My understanding is that it is not purely a government enterprise, but an arrangement on the part of private individuals, for government backing, in order to obtain a monopoly of the radium business. This is not a logical proposition because the production of radium does not differ, *per se*, from the production of steel, copper or gold.

We should be justly alarmed should the government take over our smelters, refineries and reduction works; but we would indeed have further cause for unrest should the national government, in addition to taking over these things, put them in the hands of certain favored private individuals—under any working agreement —for a division of the spoils. While the legality of this procedure is very doubtful, we may be quite sure that it is without precedent in the history of our country.

It is a fundamental law of business that any enterprise is hazardous if the supply of raw material is limited. The hazard is greatly increased if the supply of raw materials is entirely shut off. As we all know, a mine is a mine; every pound of material removed from it makes the mine capable of producing so much less—it is not an inexhaustible storehouse of wealth. Therefore, when our mines are worked out we must look for others, and if they cannot be obtained we must go out of business. This applies to any industry which is engaged in the reduction and refining of materials taken from the surface of the earth. The government proposes to limit our raw material to that which we already have and, in this way, has set the date for our retirement just as definitely as if they had given us so many days or months to operate.

It has been stated that the Standard Chemical Company now controls or is trying to control the radium industry by acquiring all of the radium deposits. Were it not that the past few decades have seen the growth of trusts and monopolies, and that the people as a whole are prone to believe an accusation of this sort, thrown broadcast by any and all persons, responsible or irresponsible, it would be idle to mention this subject. As a matter of truth, the Standard Chemical Company now owns and controls less than one-half of one per cent of the known radium deposits in the section in which they are operating.

This is not a matter which effects merely the Standard Chemical Company or my personal interests in the matter; it effects not only the development of the state of Colorado, which unfortunately has suffered too much already by outside interference in her affairs, but further than this, it is a matter of national and international importance. To Colorado one must look for the world's supply of radium, and if properly conserved, there is enough to supply the world. If, on the other hand, the ores are withheld or their values are wasted by crude and improper methods of treatment, whatever value radium may have will be lost and this generation at least will derive no benefit therefrom.

Assuming that the government intends to enter the radium field, seriously, there are several practical problems which will be apparent to sensible people and which are of fundamental importance.

In order to produce radium, one must have mines. These the national government can easily obtain either by withholding undeveloped lands or by confiscation. Then the mines must be worked under the direction of competent engineers. In order to mine efficiently, one must do it scientifically; scientific mining requires training and skill. Trained mining engineers are, as a rule, men who command good salaries for their labor. No one has ever complained, I believe, of government scientists being over-paid. Those who propose that the government can produce radium without mining it as well make a virtual acknowledgment of business incompetency, because the business is hazardous enough when one is assured of his supply of raw material.

I do not mean by this to cast reflection upon the scientific investigations made by government men in this or any other research which they have undertaken or may undertake. The business men, however, are compelled to recognize the difference between men of purely scientific attainments however profound, and the application of these things to a bank account. Scientific research is one thing and operation is another.

The problem that the national government would face in reducing carnotite ores is no greater nor is it less than that faced by a private individual or corporation. Be it said that the working out of this problem requires a faith without limit, business management of the highest degree, and sufficient reserve funds, to carry the experimental work over and through many dark and stony places.

It is a human failing, that the things we know the least about appear to be done with the greatest ease. It is not surprising, therefore, that private individuals, or government officials, should regard the reduction of carnotite ores as a problem quite on a par with the reduction of other ores of a seemingly similar refractory nature. The chemical reactions of the various elements which constitute carnotite ore are known to a limited extent, but the relations of these elements in the ore, and the difficulty of maintaining economical methods of chemical separation, present unusual difficulties which are not overcome so easily as might be expected.

The Austrian government has for some years been in the radium business. The ores available for their use are the richest which can be found or which can be hoped for. With this tremendous advantage, which America can never hope to have, the price, even with such improvements in their processes as the Austrian scientists have been able to devise, has gone up in that country instead of down. Further than this, any one who has attempted to purchase radium from the laboratories of the Austrian government have suffered delays of many months because of the exceedingly slow rate at which the radium is being produced.

Should I be in error as to what the government has already done, in the treatment of carnotite ore, it is due to the fact that their work has been carried on under a veil of secrecy and mystery. It was stated, however, (I am willing to be corrected on this and other points in which I may be in error) that about one year ago, there was available for the so-called government plant in Denver a quantity of ore of about 1000 tons containing about 9 grams of hydrous radium bromide. What was to be done with this radium after its extraction, I have no positive knowledge excepting that there were reports that it was to be divided between government and certain private individuals. It was also stated that the government process, for the extraction of the radium of this ore, had passed the experimental stage some time during the winter or spring of last year. I do not know the proposed rate at which this ore was to be treated but have heard that it was to be of 5 tons per day.

Recently the radium produced during the year's operation was introduced at a hearing before the Congressional Committee in Washington, D. C. The quantity of radium was stated to be 170 mg; this, however, was on the basis of hydrous radium bromide and the radium content would therefore be 53 per cent of this or 90 mg of radium element. It was stated that this radium had been produced from the treatment of 220 tons of the ore mentioned above, in addition to some 1900 lb. of exceptionally high-grade ore which had been purchased quite recently. Assuming that this 220 tons of ore treated was not selected as the poorest ore that could be obtained, it would contain, on the basis of 9 mg of hydrous radium bromide per ton, 1980 mg. Nineteen hundred pounds of 30 per cent ore should contain about 116 mg of radium bromide. Therefore, there seems to have been extracted 170 mg out of 2096. The efficiency of this process is, therefore, 8.6 per cent. No organization in the world, excepting a government organization could afford to operate a plant with an efficiency of 8 per cent.

The Bureau of Mines of the United States Government has endeavored to secure the passage of legislation which will withdraw carnotite lands and prevent the location of the same by private individuals, excepting under certain restricted if not prohibitory conditions. The reason given for this is stated to be that the Bureau of Mines, under this favorable condition of monopoly, may produce and manufacture radium for government hospitals. Those familiar with the matter at the present time, must surely be aware that this radium can now be bought at a price cheaper than that at which the government can produce it.

By promising to produce radium at one-third the present market price, a great injustice is done, not only to those who are producing radium, but especially to those expecting to receive relief from the application of radium as a curative agent. A person suffering with cancer, for example, cannot, as a rule, buy radium. Even if he possessed it he could not safely apply it to his ailment.

The medical profession and scientists who are at the present time willing to purchase radium for the treatment of disease and for investigation, are misled by promises of obtaining the radium at a greatly reduced price in the near future.

Without questioning the good faith of the persons who have made and widely advertised such statements at the present time their promise has not been fulfilled. Whether it ever will be fulfilled may be said to be a matter of opinion and for the future to tell. Personally —and I think I am entitled to speak with authority on the subject—I do not think the promise can be fulfilled.

The net result so far has been the discouragement of

investigation and the denial of this curative agent to those who need it. Again, purely as a matter of opinion, I am convinced that this procedure is morally wrong.

Under the present unsettled conditions it is doubtful if not improbable that any group of capitalists would care to risk any money whatsoever in developing the radium industry. And it is certain that should the present plans bear fruit, the radium industry will be absolutely a closed book so far as private enterprise is concerned. Prospecting, mining and development work will be greatly curtailed until those who have promised to produce radium at a greatly decreased cost, are able to make good and show their willingness to distribute their product among those who need it. The investigation among scientific men and institutions will be limited to those who already have a supply of radium because no one is going to buy any material which he believes can be procured, a short time hence, at one-third the market price.

So far as I can ascertain, the promise that radium will be produced at a much lower price, does not carry with it a guarantee that the ultimate buyer will get it at any price whatsoever. The agreement between the government and private parties is, as I understand it, the first 7 grams are to be retained by one man or set of men. At the present rate of 170 mg a year, one must arrive at the conclusion that it will be years before cheap radium will be distributed among physicians and scientists at large.

To those who may have been misled by more or less recent statements, that the ores now mined in Colorado are for the most part exported and thereby lost to our home people, it may be said that the small amount of ore which was mined by prospectors, up to the time the Standard Chemical Company began operation, was sent to Europe. Since that time, as a matter of record, at least 85 per cent of the carnotite ore mined in southwestern Colorado has found its way to Pennsylvania for treatment. In 1913 the exact figure was 83 per cent. The percentage was much greater than this in 1914. It would only be justice to the capitalists and engineers who have put their energies into the solving of this problem to state that the Standard Chemical Company is now producing four-fifths of the world's supply of radium. No mention has been made, I believe, in the Bureau of Mines' publications as to the magnitude, either actual or relative, of this strictly American enterprise.

In the future the radium business will be successful only under one condition—and that is large tonnage. It will always be impossible to maintain an efficient organization of engineers and scientists unless the tonnage is sufficient to pay their salaries.

Standard Chemical Co.,
Canonsburg, Pa.

Heat Insulation.—Heat insulation is as important in refrigerating plants as in boiler plants. In boiler and steam lines the struggle is to keep the heat inside where it belongs. In brine and ammonia lines, in the freezing tank and the cold storage rooms, the struggle is to keep the heat out. Under the suggestive title "Permanent Fortifications" the Armstrong Cork & Insulation Company of Pittsburgh, Pa., has just issued an interesting little bulletin in which illustrations and cost data are given from actual practice showing what can be done in the way of heat insulation by means of the company's nonpareil corkboard, insulating brick and high-pressure covering. Nonpareil high-pressure covering is made of diatomaceous earth and asbestos. It contains no cork whatever. For steam lines, it affords a permanent fortification against heat loss. It is not only an excellent heat insulator, it is also proof against water and steam.

Court of Appeals Decision in the Pyrophoric Alloy Suit

In our issue of April, 1914 (Vol. XII, p. 218), we published the decision of the District Court of the United States, Southern District of New York, in the suit of the Treibacher Chemische Werke versus The Roessler & Hasslacher Chemical Company. The decision was in favor of the complainant, the Welsbach patent in question being held to be valid as a pioneer patent and to have been infringed.

The U. S. Circuit Court of Appeals, Second Circuit (Judges Lacombe, Ward, and Rogers), has recently confirmed this decision. Mr. James Hamilton was counsel for the Treibacher Chemische Werke which won out.

The decision of the Court of Appeals is written by Judge Lacombe. In view of its importance with respect to the legal doctrine of equivalents we give the decision in full:

"The invention relates to manufacture of metallic alloys having pyrophoric action and their application to the purposes of ignition and illumination. The alloy gives forth sparks on being rubbed with a file or otherwise abraded—hence the term 'pyrophoric'. The substance is of conceded commercial utility. Being an alloy it is a compound of two or more metals. Out of fifty-five or more known and classified metals, sixteen are recognized as 'rare-earth metals'; these sixteen are divided into three groups, the cerium group, the terbium group and the ytterbium group. One of the metals in the alloy of the patent must be a rare-earth metal, and by the language of his specifications the patentee states that for the purposes of this invention the presence of the cerium is relied on as essential.

"Therefore, although there may be a mixture of rare-earth metals in the one element of the combination, cerium, or at least a metal of the cerium group, must be present. The testimony shows that an alloy composed solely of rare-earth metals will not produce the pyrophoric alloy desired; the patent indicates this. The presence of one or more of the non-rare-earth metals is essential. The specification states that the rare-earth metal cerium becomes pyrophoric if alloyed with certain other metals, in particular iron. It indicates that with about 30 per cent of iron the alloy attains its maximum of pyrophoric energy; also that the iron can be partially replaced by nickel or cobalt, but if entirely replaced by these the pyrophoric property is considerably diminished.

"The first claim reads: '1. A pyrophoric alloy, containing cerium alloyed with iron; substantially as and for the purposes described.'

"The only other claim is identical except that the iron is stated as being 30 per cent of the compound. As defendant's compound consists of cerium with from 11 to 15 per cent of magnesium, the first claim only is declared upon.

"Judge Hough, discussing the most pertinent references in the prior art, found that the patentee 'taught how certainly and knowingly to produce that' (a compound usefully pyrophoric) 'which had been observed indeed, but not understood.'

"We fully concur in this finding and in the conclusion that this Welsbach patent covers a pioneer invention and is entitled to that liberal application of the doctrine of equivalents which is usually accorded to such patents.

"In defense it is contended that defendant's product, made it is said according to the process set forth in a patent to Huber (No. 967,775, issued August 16, 1910), is not a 'metallic alloy' at all, but a chemical compound. What defendant does is first to make a metallic alloy of cerium and magnesium (in the proportions of about eighty-five to fifteen): this alloy is then subjected to the action of hydrogen in a fire-clay muffle under a temperature of 500 deg. to 600 deg. C. Changes are produced by this hydrogen treatment—the pyrophoric property of the compound is improved, possibly sufficiently to give validity to the Huber patent—and there is a conflict between the experts as to whether the resultant product has become a chemical compound or still remains a metallic alloy saturated with hydrogen. We concur in Judge Hough's finding that the weight of testimony supports the latter conclusion.

"The claim in suit mentions only iron as the non rare-earth metal, but multitudinous authorities support the proposition that, in construing a pioneer patent such as this, 'iron' should be held to mean 'iron or its equivalent'. In the specifications two other metals, nickel and cobalt, are expressly referred to as equivalents and defendant conceded

that a metallic alloy in which these, or even manganese, which like the other three belongs to a group known as the 'heavy' metals, have been substituted for the iron, would infringe.

"But the doctrine of equivalents does not confine a patentee to equivalents which he has expressly referred to. Numerous authorities sustain the proposition that when, as here, a pioneer patentee claims an alloy of one or more rare-earth metals with one or more non-rare-earths metals, he is not restricted to named varieties of either, unless he has himself restricted his claim by something in his specification, as Welsbach did, on the rare-earth side of the combination by the statement that in his alloy cerium is an essential (Winans v. Denmead, 15 How., 330). Welsbach nowhere intimates that iron is essential, on the contrary he stated his invention is the alloy of cerium 'with certain other metals, in particular iron.'

"We are satisfied that the 'equivalency' of other metals with iron is to be found not in their chemical structure, but in their functional efficiency when combined with cerium in a metallic alloy.

"Cases in this circuit (Mattheson v. Campbell, 78 F. R., 910; Richards v. Du Bon, 97 F. R., 96; Panz v. Battle Island Paper Company, 138 F. R., 48) have indicated a qualification of this theory of broad equivalents—a patentee will not be allowed to maintain a claim for more than he has discovered and disclosed. In the first of these cases the claim was for a dyestuff as a new product. The patentee described a special process by which the product was obtained, using therein a specified sulfo-acid; he stated as his discovery, invention and disclosure that 'any sulfo acid of any radical', when treated according to the process described, would produce the dyestuff of the patent. The testimony showed that there were over 100 different substances in the group of 'sulfo acids of any radical' and that only some of them—disulfo-acids, with which along the patentee had experimented—would, when treated according to the process, produce the dyestuff. The complainant contended that whenever a particular sulfo-acid, not tried before, produced the dyestuff his patent would cover it, although it did not cover sulfo-acids, which would not produce the result. We held that he could not thus 'speculate on the equivalents of his claimed invention and thereby oblige the public to resort to experiment in order to determine the scope of the claim of his patent.'

"In the second case above cited the claim was for an improvement in the art of treating tobacco leaves which consisted in 'applying an alkali to the leaves of the growing plant.' Patentee had produced his result of applying a specified alkali to the leaves, but the broad construction of the claim covering *all* alkalis was held void because it would be broader than the invention, as it would cover potash, an alkali which would not accomplish the result, and the patentee had not experimented to discover what alkalis would and what would not do so.

"The case at bar, however, does not come within the principle laid down in these decisions. Of the forty or more non-rare-earth metals it is now shown that there is one of them which will not when alloyed with cerium produce a pyrophoric compound. Some of them will produce a less efficient one than iron does, as the patent indicates, proportions must be varied with different constituents to produce better results, but we are satisfied from the record that (with the exception of metals found in such small quantities that they are known merely in the laboratory and so no one has experimented in combinating them with cerium), each and every non-rare-earth metal is a fair equivalent of iron in the compound of this patent.

"The decree is affirmed with costs."

We comment on the scope of the decision in our editorial columns.

The production of radium, uranium and vanadium in the United States in 1914 was the largest in the history of the country, according to the U. S. Geological Survey. The output amounted to about 4300 tons of ore carrying 87 tons of uranium oxide and 22.4 grams of metallic radium. A little more than 1200 tons of ore containing 28.1 tons of uranium oxide and 7.2 grams of radium, was consigned to Europe; but owing to the war some of it was held in transit. The Standard Chemical Co. and the Radium Company of America produced radium salts during the year, but with the opening of the war nearly all operations were stopped, both at mines and mills. The National Radium Institute, Denver, is now in operation under Bureau of Mines officials, and is producing radium salts.

The Non-Ferrous Metal Market

The month intervening since our last report has witnessed some striking changes in metal prices, the upward trend being most marked in the case of spelter. Copper, tin and lead also experienced a rise culminating during the first few days of Febraury, after which prices receded somewhat. Export demand for spelter, copper and lead has been in evidence and, added to domestic needs, has given the markets a firm tone.

Copper.—During the first three days of February electrolytic copper reached a high price of 14.55@14.60 cents, New York. Since that time the price has fallen off a little to about 14.10@14.20 cents. Business also has slackened and the market is dull.

Tin.—This market reached its high price on February 2, when the New York quotation was 38 cents per lb. Since then it has receded to 36. The rise was without apparent reason, and was regarded as unwarranted.

Lead.—The New York market has been set by the A. S. & R. Co. at 3.80 cents per pound. The St. Louis market has been higher than the usual parity, being quoted at 3.65@3.70 cents. The market is firm though transactions are not on a large scale.

Spelter.—Stocks of this metal, including February production, have been sold out, and considerable business has been done for April and March delivery. Prices have advanced by leaps and bounds, and the high figure may not yet have been reached. New York quotes 7.80@8.30 cents, and St. Louis 8.12½.

Other Metals.—Aluminium is in better demand and the market is stronger at 19@19½ cents, New York. The antimony market is active and large sales are reported both for export and domestic use. Prices range from 17 to 21 cents per lb. Quicksilver has shown an upward tendency, the New York price being $54@$57 per flask of 75 lb. San Francisco quotes $55 per flask.

Mellon Institute of Industrial Research

The new beautiful building of the Mellon Institute of Industrial Research, University of Pittsburgh, will be opened on Friday, February 26, 1915. There will be a reception by the trustees and director in the evening. Professor John J. Abel, of Johns Hopkins University, will deliver the first Mellon lecture under the auspices of the Society for Biological Research of the University of Pittsburgh in the lecture hall of the Mellon Institute on the evening of Saturday, February 27.

The new building which was erected at a cost of $350,000, is the gift of Messrs. A. W. and R. B. Mellon, of Pittsburgh.

The Mellon Institute of Industrial Research stands a monument to the life work of the late Robert Kennedy Duncan. Dr. Raymond Foss Bacon is the director of the Mellon Institute.

The production of manganese ore in the United States in 1914 probably did not exceed, if it equalled, that for 1913 when 4048 tons was the output. Imports have been seriously affected by the war, and during the first nine months of 1914 amounted to only 42,550 tons, or 16 per cent less than for the corresponding period of 1913. Ferromanganese also has fallen off in imports to the extent of 37 per cent, amounting to only 37,420 tons during the first nine months. Three-fourths of our imports have come from Russia and India, and the Russian product has been cut off by reason of the closing of the Bosphorus by the entrance of Turkey into the war. The effect of the shortage in the United States has stimulated interest in domestic deposits, but no important new discoveries have been made.

A Classification of High-Temperature Physical Problems

BY EDWIN F. NORTHRUP

We may assume that temperatures may be produced, artifically, ranging from 2 deg. K. to 4000 deg. K. It is not at all improbable that a temperature exceeding 4000 deg. K. may be produced by electrical means combined with high pressure. But as these methods have not as yet been developed we shall assume that 4000 deg. K. expresses at present the upper limit of temperature producible in the laboratory.

The temperature above which temperatures shall be called "high" or below which they shall be called "low" is very largely arbitrary. In order, however, that definiteness may attach to what follows we shall divide the range of producible temperature into four groups as follows:

Low temperatures.....0° K. to 233° K. (−273° C. to −40° C.)
Ordinary temperatures.....233° K. to 373° K. (−40° C to 100° C.)
Medium temperatures.....373° K. to 1273° K. (100° C. to 1000° C.)
High temperatures.....1273° K. to 4000° K. (1000° C. to 3727° C.)

Until within recent years most scientific investigation, with the exception of the study of certain radiation phenomena, has been confined to the range of ordinary temperatures. An examination of the physical and chemical constants, hitherto listed, shows how little the properties of matter outside this range have been studied. This is probably explained by two considerations; first, the means and the apparatus for investigation of the properties of matter below and above ordinary temperatures were undeveloped, and second, information acquired concerning phenomena, only exhibited by matter outside the temperature range in which contact with matter is had in the ordinary affairs of life, formerly possessed, like astrophysics, only an interest purely scientific. Industrial processes were not then, as now, very much dependent upon exact information respecting the laws and properties of matter when outside the range of ordinary temperatures.

The science of the past was engaged in detecting the invariable relations which exist between phenomena when conditions are repeated, in explaining the seeming chaos of nature by codifying the invariable relations of force manifestations, and in discovering and explaining phenomena at ordinary temperatures. This task was made vastly more difficult by the circumstance that in the range of ordinary temperature nature is manifested in her greatest complexity. More phenomena are presented to our senses at ordinary temperatures, and at these temperatures there undoubtedly exist vastly more abundant physical, chemical and life phenomena than in the lower and higher temperature ranges. The growth of our body of science had to take place in a temperature range where the complexity of phenomena was such as to make them most difficult to interpret.

Very low and very high temperature investigations are relatively simple. By passing to the high temperature range we at once eliminate from consideration all such phenomena, as crystallization, magnetism, surface coloring, production of aqueous solutions, the greater part of the phenomena of organic chemistry and a multitude of other familiar physical and chemical manifestations. The science of biology outside the range of ordinary temperatures is non-existent.

As the means and apparatus are now available for quantitative investigation in the lower and higher temperature ranges, a rapid progress should be made in the discovery and interpretation of the phenomena persistent in these ranges, because they are relatively so simple. When nature is studied, simplified, so to speak, we should be able to acquire a better understanding of the increasingly complex phenomena which appear as we bring the lower temperature range up and the higher temperature range down. In the light of our knowledge of nature simplified we shall be better able to interpret her more complex manifestations at ordinary temperatures.

By this new method of scientific investigation at extremes of temperature where nature is relatively easy of interpretation we see before us a line of attack leading to a vast territory of new knowledge. Consider as a concrete case the advance in our understanding of metallic conduction by the work of Onnes at low temperatures. He finds the conductivity, presumably by the atoms being in contact, to be infinite. Again, when others examine at high temperature the metals in their fluid state, their laws of conduction are studied free from the complexities produced by crystallization and past physical history. The temperature-resistance curves of most of them are expressed by straight lines, and, in the main, the resistance is found to get greater as the atoms become more separated by the heat expansion. How much more difficult it would be to arrive at a knowledge of the nature of metallic conduction if we confined ourselves to its study where metals are by chance hard or soft, crystallized or uncrystallized.

The study of matter at *low temperatures* has scientific interest chiefly because it leads to a better knowledge of matter at ordinary temperatures. The knowledge of the laws of matter, physical and chemical, at low temperature does not, however, appear to promise much industrially. This is chiefly due to the fact that the industrial use of temperature, outside the range of ordinary temperatures, has been to bring about new chemical equilibria which remain stable when the product is returned to ordinary temperature. By means of high temperature we produce new chemical products which are stable, and hence useful, at ordinary temperatures. At low temperature, on the other hand, new chemical equilibria are not established and matter taken from ordinary temperature to a very low temperature and again returned to ordinary temperature is, in general, unaltered in its chemical constitution. The new physical aspects assumed by matter at low temperature also, in general, disappear when the temperature is again raised, and the new physical states which exist only at low temperatures have so far, at least, found very little use in the industries.

To those who feel an interest in science chiefly because it gives an understanding of the laws and properties of matter which can be industrially utilized, high-temperature investigations will appeal with more force than low-temperature investigations. The low-temperature range has its able and enthusiastic devotees, but our interest lies in the high-temperature range. The question then presents itself to us: What kinds of investigation at high temperature are possible and useful? To help answer this question we give a classified list of high-temperature problems as these present themselves to our mind. With this list for a guide we shall be in better position to select for investigation problems which experience and judgment indicate are scientifically interesting, industrially useful or both.

High-Temperature Problems

In classifying these the high-temperature range is arbitrarily selected to lie between 1000° C. and the vaporization temperature, at atmospheric pressure, of pure graphite. In what follows respecting the production of temperature only temperatures which are producible by electrical means are considered.

In high-temperature investigation, where all life phenomena are absent, all problems for consideration are included under the general heads: Physical Prob-

lems, Chemical Problems, Electronic or Thermionic Problems and problems in the practical production and measurement of high temperature.

A mere enumeration with occasional comments on all the problems which suggest themselves which are covered by the above four headings would make an article of greater length than is here intended, and only the *physical problems* which suggest themselves are enumerated at this time.

HIGH-TEMPERATURE PHYSICAL PROBLEMS

The physical forces and properties of matter presumably manifested at high temperature and which await investigation are in part included in the list below:

1—*Gravitational Attraction of Matter.*—Is the experimental proof complete, that the gravitational attraction of matter is entirely unchanged when the temperature is raised to the neighborhood of 4000° K.? This is a somewhat difficult but an extremely important question to answer definitely. It is probable that the requisite temperature could be obtained by a chemical reaction, as by thermit.

2—*Surface Tension.*—Does it belong to all matter in the molten state? How does its value in the case of molten metals change with increase in temperature? Is it due to a gravitational, electrical, chemical, or to an un-named force of attraction between molecules or atoms? Surface tension of molten metals could probably be investigated by taking instantaneous photographs of falling globules of the metal and observing the vibration period of the globules.

3—*Molecular Cohesion.*—What are the laws of alteration (or weakening) of molecular cohesion of the highly refractory solid elements and certain of their useful alloys, etc. with great increase in temperature? This is the problem of finding suitable materials for high-speed cutting tools which may be run red hot, and of the tensile strength of wires and cables which must be used under conditions of high temperature. How do the highly refractory metals, W, Mo, and Ta, etc., preserve their elastic properties at high temperature? Is the internal molecular friction increased or lessened at high temperature in materials of this class?

4—*Molecular Adhesion.*—What metals, when in the molten or vapor states, will adhere to or "wet" certain other higher melting point metals in the solid state? Thus, gold wets molybdenum, tin does not wet tungsten. Do metallic liquids or vapors ever wet non-metallic materials? What are the facts and laws regarding the metallic coating of surfaces at medium or high temperatures without the use of aqueous solutions? Inquiries in this line would appear to have commercial importance.

5—*Forces Which Cause Materials to go Into Solution.*—How are materials related as solvents and solutes at various high temperatures? Thus molten copper dissolves copper oxide and also nickel. It does not dissolve molybdenum or tungsten. Why? What are the characteristics or properties of a material or element which which determine its solubility at high temperature in a molten element? This problem is the immense one concerning the formation of alloys and the segregations which occur when the temperature is lowered.

6—*Thermal Expansive Forces.*—What are the curves of volume versus temperature of materials, especially the non-gaseous elements when in the molten or vaporous states? Do liquid metals increase in volume proportionally to the temperature and does their increase in volume maintain the same ratio to their increase in some other physical property, as their electrical resistance? Is there any case where the second property can be deduced from a knowledge of the first? Do the vapors of the easily vaporizable metals obey the ordinary gas laws, as Boyle's law? Will a knowledge of the laws of expansion of molten metals of high vaporization point, as tin, enable the property of expansion to be conveniently used for the accurate measurement of very high temperature?

7—*Specific Heat.*—The specific heat of nearly all substances which are non-gaseous at very high temperature await precise determination. Thus, if the specific heat of tungsten or molybdenum were accurately known up to their melting points an excellent calorimetric method of measuring very high temperature would appear to be easy to develop.

8—*Vapor Tension and Boiling Points.*—The vapor-tension curves of practically all materials, which are solid or liquid in the high-temperature range, await determination. Some of the molten metals, as gold, show considerable evaporation at temperatures considerably under their boiling point, while others, as copper and tin, show comparatively little evaporation until near their boiling point. An accurate determination of the boiling points at atmospheric pressure of most of the metals is much needed. There appear to be good reasons for supposing that accurate determinations of the boiling points of several of the pure metals in the high-temperature range, would furnish a series of "fixed points" of high temperature which would be very useful for calibration purposes.

9—*Fusion Temperatures.*—An accurate determination of the fusion points of many of the pure metals has already been made, but much remains to be done respecting fusion points of the highly refractory metals and certain of the salts. It is especially desirable to determine how the fusion temperature of several of the metals, especially of the precious metals, is influenced by the nature of the vapor or gas in which the fusion of the metal takes place. Thus the fusion temperature of the platinum and platinum rhodium used in thermocouples is much lower in a C0+N atmosphere than in an oxidizing atmosphere. In what atmospheres are the fusion points of the various metals normal and how and to what extent are they affected by other atmospheres?

10—*Viscosities.*—Practically nothing is known in a quantitative way respecting the viscosities of molten salts and molten metals in the high-temperature range. Thus, pure molten iron is said to be quite viscid while pure molten copper is extremely limpid. The velocity of flow of molten metals and molten lavas, etc., largely depend upon the viscosity of the materials.

11—*Compressibility.*—The compressibility of many elements and inorganic compounds with application of pressure and high temperature, is a geophysical as well as a physical problem of importance. This line of investigation is being followed by the Geophysical Laboratory, at Washington. A successful attack upon the problem involves the ability to produce a localized high temperature in the zone of compression and to maintain the surrounding zones cool to permit the compression cylinders to maintain their mechanical strength. All matter at a great depth below the earth's surface is presumably at high temperature and under great pressure. Hence experimental information upon the compressibility of matter at a high temperature gives information regarding the state of the earth's interior. Experiments should begin with a study of the compressibility of the metallic elements when at a high temperature. The resistivities of the metallic elements should be simultaneously studied as undoubtedly there is a close connection between the resistivities of the metals and the closeness of the packing of their atoms or atomic groups.

Query: Is it experimentally possible to bring certain metallic vapors to the condition of being at the critical temperature and at the critical pressure?

12—*Elasticity.*—How is the elasticity, or the ability to maintain or prolong vibration, related to temperature, in the case of those metals and alloys which only fuse at a high temperature? How is the logarithmic decrement of a tungsten wire subjected to rotational vibration related to temperature in the region of high temperature? Or how is its elastic fatigue affected by high temperature? Can all "physical past history" be wiped out by application of high temperature in the case of a material which is not fused by the high temperature? Will increase of temperature which increases molecular separation with a related increase in electrical resistance, in the case of most metals, diminish or increase internal molecular friction? Thus Prof. Malcolm MacLaren has shown experimentally that elevation of temperature greatly reduces magnetic hysteresis. Should we therefore expect that a tuning fork of tungsten would continue to vibrate longer above 1000° C. than it would under this temperature? The experiment could easily be tried for the torsional vibration of tungsten, molybdenum and tantalum wires.

13—*Thermal Conductivity.*—The study of thermal conductivity at high temperature is an extensive field. The inquiry should extend to the relations which thermal conductivity bears to electrical conductivity in the case of elements and alloys. Is there a sudden transition, increase or decrease, as there is in the case of electrical conductivity when a metal changes state? A method has been devised and a piece of apparatus constructed, by the writer, for answering this question.

The investigation of thermal conductivities at high temperatures of inorganic compounds and refractories has a high value for engineers engaged in the construction of high-temperature furnaces. Will these investigations answer the query, whether the transport of heat by conduction is entirely a phenomenon of the passing along of molecular vibrations, or is it due in part or wholly to agitations brought about and passed along by the bombardment of molecules with electrons?

The thermal conductivity of powders determined as a function of their compression should be examined. Even metallic powders when fine grained, as powdered molybdenum, for example, show a high electrical resistance when not under compression and a fairly low resistance when under compression. Is there an analogous relation for the thermal resistance? On account of surface thermal resistance it is probable, that very high thermal insulation might be obtained by concentric metallic cylinders of very thin metal with very small separation between the layers. What would be the thermal conductivity of a stack of alternate layers of thin tin-foil and tissue paper? The writer knows of no data on this subject.

14—*Cooling Curves.*—The determination of cooling curves of the metals, and especially of the alloys, and the relations which they bear to the resistivity curves, is a highly important line of investigation. If the resistivity curves of metals and alloys are definitely related (as there are reasons to suppose they are) to the cooling curves, it is important to determine these relations precisely on account of the light which this information would shed upon the nature of metallic conduction, and because of the practical value to be derived in studying the physical properties of alloys, by determining their resistivities curves by the very simple methods which the writer has devised.

15—*Radiation.*—The radiation from hot bodies offers the most unlimited field of investigation at high temperatures. In addition to the many problems in optical pyrometry, in the study of spectral lines, in the motions of stellar bodies determined by the shifting of their spectral lines, in addition to the problems of absorption of spectral lines by metallic vapors, and the whole question of the synchronism of molecular and atomic vibrations with ether radiations of definite wave lengths, there are a few less commonly stated problems:

(*a*)—What are the laws of metallic reflection from the bright surface of molten metals? Thus the surface of copper at 1600° C. in a reducing atmosphere makes an excellent mirror and gives an image of objects which receive their illumination from the surface of the mirror itself. Is the light in this case polarized at any angle? What in general are the laws of the phenomena?

(*b*)—Do molten salts at very high temperature, which are known to be good conductors of electricity, retain their optical transparency? If they are optically transparent how does their electrical conductivity vary with the frequency when alternating current is used? What is the list of materials which are transparent above 1000° C.? The writer has thought out a method by which this determination could be affected.

(*c*)—As the temperature of a metallic vapor is gradually elevated to near 3700° C. will new spectral lines appear with sufficient suddenness, or will existing lines change in character, so as to permit the temperature to be measured with a direct vision spectroscope? The "cascade attachment" of the Northrup high-temperature furnace offers a perfect means for investigation along many lines of high-temperature radiation.

(*d*)—What are the indices of refraction of molten salts where these are transparent?

(*e*)—What are the coefficients of absorption for light of different wave lengths of the metallic vapors? Much could be learned regarding the vibration frequencies of metallic atoms by the study of the light absorption of metallic vapors.

16—*Osmotic Pressure.*—Can a porous diaphragm be found which molten salts will "wet" at a high temperature? If so, may it not be possible to observe at high temperature the phenomenon of osmotic pressure with molten salts? It is well known that molybdenum is wetted by certain metals, as molten copper and molten aluminium. Could not a diaphragm be made of strongly compressed molybdenum powder and by using this diaphragm to separate an alloy, of say tin and copper on one side and pure tin on the other, to produce the phenomenon of metallic transfusion and metallic osmotic pressure?

17—*Radioactivity.*—Has it been finally and definitely proved that excessively high temperature will not induce either a state of radioactivity or new radiations analogous to X-rays?

18—*Solubility of Gases in Molten and Solid Metals.*—Will a bulb of more or less porous material entirely submerged in a molten metal, as tin above 1000° C., form a gas-tight vessel? What is the solubility, if any, in the different molten metals at high temperature of various kinds of gases? Tungsten and molybdenum heated in a CO+N atmosphere always become crystalline and brittle. Is this due to an absorption and chemical combination with the CO gas? The properties of most metals are much modified when heated in various atmospheres to a high temperature but practically no definite data are available, respecting just what occurs.

19—*Solubility of Metals in Fused Salts.*—Does this ever occur and if so how is the electrical conductivity of the salt affected?

20—*Electrical Conductivity.*—The investigation of electrical conductivity should include:

(*a*)—The E. C. of all the elements which maintain the solid or liquid phase at high temperature. The so called insulators which are elementary substances, as liquid sulphur, should be carefully examined for their electrical conductivity when at high temperature and under such pressure as can be obtained.

(*b*)—E. C. of the metallic elements in the vapor phase at different pressures and different temperatures. Experiments already made by the writer (*Journal* of the Franklin Institute, March, 1915) show that the conductivity depends upon many factors and when measured between a tungsten wire and the walls of a graphite cylinder in which the wire is axially located, is asymmetric; that is the conductivity depends upon the polarity of the wire. Furthermore, different results are obtained when the conductivity is measured with alternating current of different frequencies.

(*c*)—The E. C. of the non-metallic elements in the gaseous phase at high temperature and under high pressure. (The conductivity at low pressures has been extensively investigated.)

(*d*)—The E. C. of several metallic alloys when molten has been examined, but many yet remain.

(*e*)—The E. C. of molten salts for alternating current of different frequencies.

(*f*)—The E. C. for direct current of molten salts under conditions which would reveal an asymmetric conductance, if it exists.

(*g*)—The E. C. at high temperature of standard refractory materials and a determination of the percentage of the conductivity which may be ascribed to hot gases contained in the interstices of the refractories.

(*h*)—A study should be made of the cause of an apparent increase, observed by the writer, in the specific inductive capacity of both hot gases and refractories when attempting to measure the E. C. of these with alternating current of different frequencies.

21—*Electromotive Force.*—The study of the production of e.m.f. chemically in primary cells has been confined for the most part to aqueous solutions at ordinary temperature. There is a large field for investigation at high temperature of the e.m.f. obtainable; (a) between two fused salts separated by a porous partition (b) between a fused salt and a solid, and (c) between two fused metals separated by a porous partition of compressed tungsten powder. May not primary batteries of very considerable e.m.f. and of possible high efficiency result from this study? Should not the matter be reopened of attempting the consumption of carbon in a manner to give rise directly and efficiently to electrical energy? This is one of the great problems which investigations with high temperature are most likely to solve.

The writer has observed that when working above 1200° C. that practically all combinations of two or more materials give rise to electromotive forces—often very troublesome when accurate measurements are being attempted. In fact, because of this, all his measurements of electrical conductance at high temperature of the metals are now made with an alternating-current galvanometer as a detector and alternating current of 25 cycles as the measuring current. The magnitude and the causes of these electromotive forces in the case of certain combinations of typical materials deserve investigation.

22—*Thermoelectromotive Force.*—We have to inquire, (a) What are the thermoelectromotive force curves at high temperature of combinations of solids, (b) of combinations of metallic liquids (as molten tin versus molten lead) (c) of combinations of metallic vapors (as zinc vapor versus cadmium vapor), (d) of the combinations of the solid versus liquid phase of the same metal, (e) of combinations of a solid metal versus another liquid metal, (as W versus molten Sn), (f) of combinations of molten salts.

How little we know about these matters may be determined by consulting any of the standard tables of the physical constants.

23—*Specific Inductive Capacity.*—There are reasons to suppose that a slab of refractory material contained between two slabs of graphite will exhibit the phenomena above 1200° C. of a very leaky condenser having a dielectric of large specific inductive capacity.

24—*Thomson and Peltier Effects.*—As far as the writer knows these phenomena have only been studied at ordinary temperatures.

25—*Mechanical Forces.*—It is always assumed, but as far as the writer knows has never been experimentally proved, that inertia and centrifugal force exist unchanged in matter at all temperatures and obey the same Newtonian laws at 4000° K. as they do at ordinary temperature. Should not this assumption be tested? For example, suppose a large spherical pendulum bob were filled with thermit, would the period remain unaltered while the thermit reacted? The writer is mentally constituted so that he takes nothing for granted regarding which there is an opportunity for obtaining experimental evidence.

26—*Engineering Data.*—There is an unlimited quantity to be obtained of engineering data regarding the physical properties of matter at temperatures exceeding 1200° C. The limitations of the nichrome and platinum-wound laboratory furnaces are largely responsible for the paucity of information respecting the physical properties of matter above 1100° C. or 1200° C.

The above article has been written for the double purpose of assisting the writer in the selection of the problems of high-temperature investigation which he would attack, and to present to the readers of this journal (in an all too inadequate way) the immensity and the fruitfulness of this rapidly enlarging field of investigation. The greatest results can only be expected through interested co-operative effort.

The chemical field and the construction of practical devices have not been considered, though it is probable that the most important developments commercially will come from a study of high-temperature chemistry. It is in the study of high-temperature chemistry, which the writer thinks should be called electrothermics, rather than in the study of high-temperature physical problems that the greater progress commercially may be expected.

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The International Engineering Congress announces that the technical success of the Congress is now well assured. From 200 to 250 papers will be presented, representing 18 different countries, so that the Congress will be truly international in character. Membership in the Congress with the privilege of purchasing any or all volumes is open to all interested in engineering work.

Monazite sand in Brazil is found in commercial quantities only on the foreshore at certain points on the coast of the state of Espirito Santo and a few miles north of the town of Prado, in the state of Bahia. The foreshore belongs to the government and leases are granted under the direction of the Minister of Finance. There are at present two active concessions and one passive.

Exports of tin from the Federated Malay States from July 1 to December 31, 1914, amounted to 24,140 tons, as compared with 26,244 tons in the corresponding period of 1913. The total exports of tin for 1914 amounted to 49,042 tons, as compared with 50,128 tons in 1913.

Stratton's Independence milled during December, 1914, 9400 tons of low-grade mine and dump ore. The net profit to the company for the month was $6700.

Leaching a Zinc-Lime Ore with Acids*

BY O. C. RALSTON AND A. E. GARTSIDE

In looking over the low-grade and complex ore resources of Utah, it was found that in the two largest mining districts in the State there was a certain type of ore which consisted essentially of calcium and zinc carbonates, more or less associated with some insoluble silica and silicates, the zinc ore being a replacement in limestone.

The following analysis of ore, from the May Day mine, of the Tintic district is representative: Insoluble, 37.4 per cent; CaO, 12.96 per cent; Fe, 4.19 per cent; Al_2O_3, trace (acid soluble); Zn, 15.7 per cent; Pb, 0.55 per cent; Au, 0.24 oz. per ton; Ag, 0.30 per cent; S, 0.65 per cent; CO_2, 19.84 per cent.

An approximate mineralogical analysis calculated from these data, dividing CO_2 between CaO, Zn, and Pb, would be:

	Per Cent
Silica, SiO_2	37.40
Limestone, CaO_3	23.15
Limonite $(Fe_2O_3)_2(H_2O)_3$	6.00
Pyrite, FeS_2	1.20
Calamine, $H_2Zn_2SiO_5$	2.31
Smithsonite, $ZnCO_3$	27.70
Cerussite, $PbCO_3$	0.70
Total per cent	97.46

The undetermined material perhaps includes some alumina, as well as some water of composition, provided part of the smithsonite has been altered to hydrosincite. The above analysis, however, accords fairly well with a qualitative microscopic examination of the ground sample.

There are several other types of oxidized ores of zinc which are much more abundant, but this one is of interest on account of the high percentage of lime and the rather large amount of gold present, the presence of this much gold being somewhat unusual in the Tintic district, at least for a zinc ore in limestone.

It is of considerable interest to see whether the zinc could be leached out of the ore with acids or other solvents as a preliminary to cyaniding the gold. To maintain a fairly pure electrolyte for the decomposition of zinc, it is necessary to keep the iron from going into solution. As this particular ore contains such a low percentage of iron it probably would not be difficult to keep the electrolyte reasonably free from iron, while the presence of lime would doubtless be permissible in such an electrolyte because it does not deposit at the decomposition voltages of the zinc salts. However, it can cause trouble in another way, for when currents of high density are used, a sparingly soluble hydrate is formed at the cathode. On account of the low solubility of calcium sulphate, this latter trouble is rarely met in a solution resulting from sulphuric acid leaching.

However, the precipitation problem was left till it was possible to see what could be done with acid leaching; therefore, the purpose of this paper is to report only what seem the most fundamental and important results of these acid leaches, without too much detail regarding connected problems. Other types of leaching, such as alkaline ammonium carbonate, caustic soda, etc., have been tried, but will be reported later.

Leaching with hydrochloric and sulphuric acids was given first consideration for the reason that both can be made very cheaply in the Salt Lake Valley, the one from the salt in the Great Salt Lake, which is present in amounts varying around 26 per cent by weight, and the other from the SO_2 of the smelter gases from four large smelting plants, all within thirty miles of one another and not more than a hundred miles distant from most of the deposits of ore.

Three series of tests were run on the raw ore, crushed to 150 mesh to liberate the zinc minerals as thoroughly as possible, and in lots of 33.33 gms. for each test, with varying amounts of acid and water to make up 100 cc of solution.

The proportions used in these tests were such as to suit the leaching bottles at hand, which were of the ordinary 150-cc type often used for agitation tests in cyaniding. The bottles were placed in an agitator which turned them over completely, end for end, about once every second. All of the acid tests were carried on at room temperature. The pulp after agitation was filtered either with a Buechner funnel or with the alundum filtering dishes now to be had on the market, portions of the filtrate taken for titration and the tailings washed, dried and weighed. The filtrate was analyzed for zinc, lime and iron to check up the analyses for the same elements, on the heads and tailings. The final acidity was also determined in the filtrate.

Description of the Tests.—In the first series of tests identical samples were treated with each acid in amounts insufficient to dissolve the zinc and lime in the lower concentrations, up to amounts of acid sufficient to dissolve all the zinc, lime and iron and still allow residual acid. These are the No. 1 leaches recorded in Table I.

The second series of tests was much the same as the first with the exception that chloride of lime was added to the solutions in anticipation of the solution of the gold by means of the chlorine liberated by the action of acid on the chloride of lime. These leaches are the No. II leaches recorded in Table I. Whether such a method would be advisable in practice is open to question, but it must be remembered that application of cyaniding after acid leaching will require neutralization and probable high consumption of cyanide. Direct application of the old chlorination process, however, could make this a "one-solution" process.

The last series of tests, numbered III in Table I, was run with amounts of acid sufficient to dissolve only about one-fourth of the zinc and lime in each leach, and four of these leaches in succession were applied to the ore. That is, the samples in duplicate, were given a leach with a solution of acid which had seemed by previous tests to be the most advantageous in the dissolving of zinc selectively as compared with the lime, and in amount sufficient to dissolve only a little more than a fourth of the zinc and lime present in the ore. After agitation and filtration the so lution was taken for analysis and the residue leached with the same amount of the same acid, again filtered, dried, weighed and treated in the same way twice again. By this time most of the zinc had been leached out and the tests were discontinued. The object of the series was to compare the two acids in efficiency at different parts of the leach and to see in what order the constituents of the ore went into solution.

The Results. All of the data of the tests are to be found in Table I, just described.

Taking tests I-a to I-f, where hydrochloric acid is solvent, it can be seen that there is sufficient acid in I-a and I-b to dissolve only the zinc in the ore. The result that is of interest from these first two tests is the acid efficiency (amount of acid consumed per unit of zinc extracted) rather than the extraction of the zinc obtained.

The amount of acid necessary to dissolve all the zinc in the samples treated is 5.83 grams. The efficiency of

*Contribution from the Metallurgical Research Laboratory, D. A. Lyon, metallurgist in charge, of the University of Utah, in cooperation with the U. S. Bureau of Mines. O. C. Ralston is assistant metallurgist of the U. S. Bureau of Mines.

[1] G. F. Loughlin, "The Oxidized Zinc Ores of the Tintic District, Utah," *Econ. Geol.* (1914), page 1.

Table I

Test No.	Wt. Heads, Grams	Wt. Tails, Grams	Time in Hours	Acid	Strength Lb./Ton	Strength %	Grams Acid Before	Grams Acid After	Grams Acid Consumed	Efficiency lb. Acid / lb. Zinc	Efficiency %	CaO Grams Heads	CaO Grams Tails	CaO Grams % Ext.	Fe Grams Heads	Fe Grams Tails	Fe Grams % Ext.	Av. Ounces Heads	Av. Tons Tails	Av. % Ext.	Zinc Grams Heads	Zinc Grams Tails	Zinc Grams % Ext.	$CaCO_3$ Used Grams	$CaCO_3$ Used Lbs. per Ton Ore
I. a	33.33	31.7	21	HCl	40.5	2	2.025	0	2.025	2.38	46.7	4.32	3.83	11.34	1.45	1.45	0				5.23	4.28	18.15		
b	33.33	29.5	21	HCl	81.0	4	4.05	0	4.05	2.16	51.5	4.32	3.45	20.16	1.45	1.45	0				5.23	3.26	37.8		
c	33.33	20.5	21	HCl	203.0	10	10.15	0	10.15	2.43	45.8	4.32	1.47	66.0	1.45	1.45	0				5.23	1.05	80		
d	33.33	32.9	22	HCl	224	11.2	11.2	0	11.2	2.30	48.4	4.41	0.98	77.7	1.60	1.60	0				5.43	.57	89.5		
e	33.33	33.0	22	HCl	224	11.2	11.2	0	11.2	2.30	48.4	4.41	0.95	78.5	1.60	1.60	0				5.43	.57	89.5		
f	33.33	22.1	22	HCl	340	17.0	17.0	2.75	14.25	2.62	42.5	4.41			1.60	1.60	0				5.43				
g	33.33	32.9	21	H_2SO_4	38.5	2	1.975	0	1.975	4.20	35.8	4.32	4.32	0	1.45	1.45	0				5.23	4.76	8.98		
h	33.33	31.9	21	H_2SO_4	76.75	4	3.838	0	3.838	2.52	59.6	4.32	4.32	0	1.45	1.45	0				5.23	3.71	29.04		
i	33.33	30.7	21	H_2SO_4	185.0	10	9.25	0	9.25	2.70	55.6	4.32	4.32	0	1.45	1.45	0				5.23	1.80	65.06		
j	33.33	28.2	22	H_2SO_4	303.5	15.2	15.175	0	15.175	3.19	47.0	4.41	4.41	0	1.60	1.60	0				5.43	.68	87.5		
k	33.33	28.0	22	H_2SO_4	303.5	15.2	15.175	0	15.175	3.19	47.0	4.41	4.41	0	1.60	1.60	0				5.43	.68	87.5		
l	33.33	26.2	22	H_2SO_4	454	22.7	22.7	3.8	18.9	3.75	40.0	4.41	4.41	0	1.60	1.24	22.45				5.43	.39	92.9		
II. a	33.33	31.3	16.5	HCl	40.5	2	2.025	0	2.025	4.3	25.9	4.99	3.93	21.2	1.42	1.39	0	0.24	0.08	66.6	5.03	4.56	9.3	1.67	100
b	33.33	31.75	16.5	HCl	40.5	2	2.025	0	2.025	11.24	9.9	5.68	4.22	25.7	1.42	1.38	Trace	0.24	.08	66.6	5.03	4.85	3.6	3.33	200
c	33.33	28.8	16.5	HCl	81.0	4	4.05	0	4.05	3.09	36.0	4.99	3.37	32.5	1.42	1.40	Trace	0.24	.12	50.0	5.03	3.72	26.0	1.67	100
d	33.33	29.16	16.5	HCl	81.0	4	4.05	0	4.05	2.96	37.6	5.68	3.55	37.5	1.42	1.39	Trace	0.24	0.6	75.0	5.03	3.76	25.1	3.33	200
e	33.33	33.84	16.5	H_2SO_4	38.5	2	1.975	0	1.975	5.05	29.7	4.99	4.81	3.6	1.42	1.38	Trace	0.24	.16	33.3	5.03	4.64	7.8	1.67	100
f	33.33	35.04	16.5	H_2SO_4	38.5	2	1.975	0	1.975	13.17	11.4	5.68	5.13	9.7	1.42	1.41	0	0.24	.16	33.3	5.03	4.88	3.0	3.33	200
g	33.33	32.89	16.5	H_2SO_4	76.75	4	3.838	0	3.838	2.89	52.0	4.99	4.87	2.4	1.42	1.40	Trace	0.24	.16	33.3	5.03	3.70	26.4	1.67	100
h	33.33	35.3	16.5	H_2SO_4	76.75	4	3.838	0	3.838	5.40	27.8	5.68	5.52	2.8	1.42	1.50	Trace	0.24	.14	41.6	5.03	4.32	14.1	3.33	200
III. a	33.33	28.38	17	HCl	81.0	4.05	4.05	0	4.05	1.85	60.0										5.23	3.05	41.7		
	33.33	23.24	17	HCl	81.0	4.05	4.05	0	4.05	2.45	45.5										5.23	1.40	73.3		
	33.33	17.7	18	HCl	81.0	4.05	4.05	0	4.05	5.12	21.7										5.23	.61	88.3		
	33.33	13.1	18	HCl	81.0	4.05	4.05	2.1	1.95	3.70	30.1											11	37.7		
b	33.33	28.43	17	HCl	81.0	4.05	4.05	0	4.05	1.90	58.8										5.23	3.10	40.8		
	33.33	23.19	17	HCl	81.0	4.05	4.05	0	4.05	2.50	44.7											1.48	71.7		
	33.33	17.37	18	HCl	81.0	4.05	4.05	0	4.05	4.50	24.7											.58	88.9		
	33.33	12.97	18	HCl	81.0	4.05	4.05	2.2	1.85	3.78	29.4											11	98.0		
c	33.33	31.38	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.60	58.4										5.23	3.75	28.3		
	33.33	28.47	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.65	56.8											2.30	56.0		
	33.33	25.05	18	H_2SO_4	76.8	3.84	3.84	0	3.84	3.69	40.6											1.26	75.9		
	33.33	23.15	18	H_2SO_4	76.8	3.84	3.84	0	3.84	1.63	13.0											.93	82.3		
d	33.33	31.75	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.54	59.2										5.23	3.72	28.5		
	33.33	28.36	17	H_2SO_4	76.8	3.84	3.84	0	3.84	2.48	60.5											2.17	58.5		
	33.33	25.12	18	H_2SO_4	76.8	3.84	3.84	0	3.84	3.84	39.1											1.17	77.6		
	33.33	23.0	18	H_2SO_4	76.8	3.84	3.84	0	3.84	13.92	11.5											.88	83.1		

the acid in these two tests, expressed in "per cent of the acid used up which was used to dissolve zinc," was 46.7 per cent and 51.5 per cent respectively. This shows that in spite of using such a small amount of acid, it was not possible to make all of it go toward dissolving zinc alone, but that instead some of it went to dissolve other soluble constituents of the ore. By testing the leach solution it was found that the rest of the acid dissolve the lime, and almost no iron was dissolved.

Test I-b is known to have suffered a small leak during agitation, causing a loss of acid, but being identical with test III-a, was not repeated. The efficiency of acid in test III-a was 60 per cent.

Test I-c was with more than enough acid to dissolve all the zinc but not quite enough to dissolve in addition all the lime. An 80 per cent extraction of the zinc was obtained, but the figure on efficiency of the acid fell to 45.8 per cent, a result which seems to be low when compared with the next two tests which were run in duplicate.

These two tests, I-d and I-e, were run with just sufficient acid to dissolve all the zinc and lime in the ore, but no iron. An 89.5 per cent extraction of the zinc resulted, with an efficiency of acid expenditure of 48.4 per cent, but it was noticed that a trace of iron was beginning to dissolve.

Finally, test I-f was run with sufficient acid to dissolve all the zinc, lime, and iron. The results show that after twenty-hours of contact a good portion of the iron had not dissolved, as considerable free acid was left in solution.

Summing up this series of tests with hydrochloric acid, we see that it is possible to get an 80 per ecnt extraction of zinc, or better, with about a 50 per cent efficiency of acid to give a solution that is practically free of iron and hence admirably adapted to electrolysis of the solution for obtaining the zinc. This is because lime does not tend to deposit at the voltage necessary for deposition of zinc, and, moreover, because there is no excess acid in this solution.

By increasing the amount of acid applied while the increased extraction of zinc is small, iron tends to go into solution and excess of acid is left, both results being undesirable from the standpoint of electrolytic precipitation. Direct production of metal and regeneration of acid are, of course, the main reasons for wanting to use electrolytic precipitation. The acid efficiencies of this series of tests are shown plotted in Curve I.

In passing it might be well to call atention to the utility of the units used in Curve I. Here, plotted against the various strengths of acid, are to be found the efficiencies of the acid expressed in two different units. For use by the mill man we have expressed the acid efficiency in terms of "lbs. acid used up per lb. zinc, dissolved." For more general application, however, we have also expressed the acid efficiency by giving percentage of the consumed acid which was used in dissolving zinc. This immediately shows what percentage of the acid is used in dissolving materials other than zinc, while the mill man's "lbs. acid per lb. zinc" does not show what efficiency is obtained until his figure is compared with the amount of acid necessary to dissolve 1 lb. zinc where no acid is wasted. This amounts to 1.112 lb. HCl per lb. zinc in the case at hand and 15 lb. of H_2SO_4 per lb. of zinc when sulphuric acid is used. The strengths of acid used are also expressed in two sets of units—one in percentage by weight of acid in the solution and the other in pounds acid per ton of solution used. This method of having both practical and absolute units should prove useful and save transposition of figures.

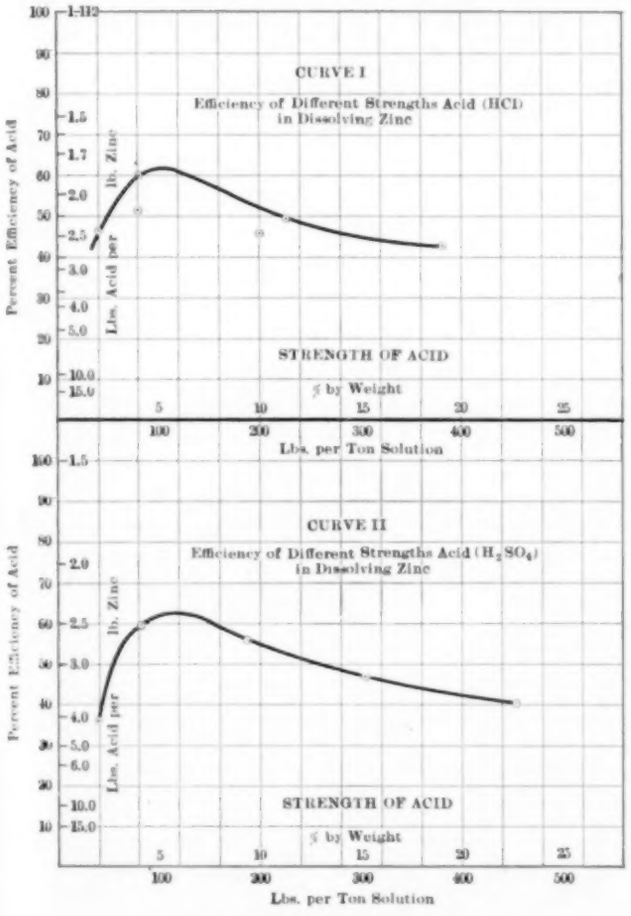
Tests, I-g to I-l (Curve II) with sulphuric acid, were conducted in exactly the same sequence, the first three being with increasing amounts of acid, insufficient in every case to dissolve all the zinc and lime, while the next two are duplicates with an amount of acid just sufficient to dissolve zinc and lime and the last one with an amount of acid sufficient to dissolve all the zinc, lime, and iron. The iron did not dissolve appreciably until the last test, but here again we find that only a portion of the iron was soluble so that some free acid was left.

The percentages of extraction of the zinc tend to run a few per cent lower than in the case of hydrochloric acid, when compared on a pound for pound basis, but it

must be remembered that the chemical equivalent of a pound of sulphuric acid is less than that of a pound of hydrochloric acid, being roughly $\frac{72}{98}$.

The plot of acid efficiences for H_2SO_4 (Curve II) shows a very smooth curve with a decided maximum at a point where about 6 per cent strength of acid is used, and this maximum attainable efficiency is 63 per cent. A like maximum would seem to be discernible in the case of the tests with hydrochloric acid (Curve I) but not enough points have been determined to place it exactly.

Again, we find it possible to get up to an extraction of 87.5 per cent with an acid efficiency of 47 per cent, while to go further in extraction of the zinc lowers the acid efficiency, fails to increase appreciably the amount of zinc extracted, and takes iron into solution, as well as leaving unconsumed acid to hinder electrolysis.



FIGS. 1 AND 2—EFFICIENCY CURVES

It is an interesting coincidence that if we examine the analysis of the ore we find, with respect to the two soluble constituents, zinc and calcium, the perecentage of zinc is 63 per cent of the sum of the zinc and calcium, while our maximum acid efficiency is likewise at 63 per cent. In other words, at the point of maximum efficiency zinc and lime go into solution in amounts proportionate to the percentages in which they are present in the ore, with no preference in solubility for either constituent. As calcium stands higher than zinc in the electromotive series, this point of non-selective solubility is of considerable interest and its explanation is not exactly clear.

The tests numbered II were made with insufficient acid to dissolve all the zinc; furthermore, varying amounts of chloride of lime were added to supply chlorine for solution of the gold. The zinc extractions were very low, because much of the acid combined with the chloride of lime (which contained 41.6 per cent CaO). On that account the zinc extractions and the efficiencies of expenditure of the acids are of little interest for the time being and only the extractions of gold will be noted. It is seen that in all cases the extractions of the latter were higher in leaches containing hydrochloric acid and bleaching powder than in those leaches where sulphuric acid was used with bleaching powder; however, the amount of bleaching powder used to get these extractions was rather large, varying from 3 to 10 per cent of the weight of the ore. This highest extraction of gold was 75 per cent.

However, tests of this magnitude and under these conditions are not regarded as conclusive, so the inference is that the gold seems to be somewhat readily soluble in solutions containing chlorine. The extraction of the gold will not be further considered in this connection, for the special object of this paper is to call attention to the possible acid efficiency in extracting zinc from an ore so high in lime.

Going back to the maxima in the acid efficiency

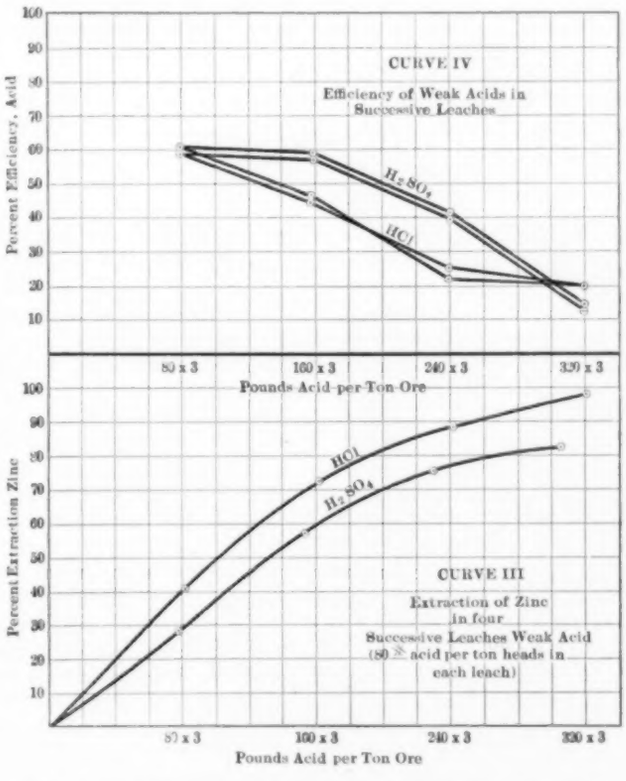


FIG. 3 AND 4—EFFICIENCY AND EXTRACTION CURVES

curves, we find that a certain strength of solution seemed to give the most advantageous conditions for leaching and since not enough acid had been used to extract all the zinc, it was thought advisable to see if successive leaches of acid of this strength would extract all the zinc, and whether they would change in their acid efficiency.

These tests constitute III-a to III-d—III-a and III-b being duplicates with four successive leaches of HCl, and III-c and III-d being duplicates of H_2SO_4 leaches—four in succession in each case.

The results are plotted in curves III to V. Curve III shows the percentages of zinc extracted after each successive leach, there being four points determined on the curve for each acid. Again we find that, pound for pound, hydrochloric acid will extract more zinc than sulphuric acid.

In order to see if a chemical equivalent of H_2SO_4 would dissolve as much as a chemical equivalent of HCl, the units of Curve III were changed from "pounds per ton" to "moles of acid used," and replotted in curves V. We find from this diagram that hydrochloric and sulphuric acid give identical curves and extract exactly the same percentage of zinc, as far as the chemical equivalents go. Though chemically, one is no better than the other, at the same cost per pound, the hydrochloric acid would have the advantage.

Curve III is of interest to the mill man, while Curve V is of interest to the scientist. The fact that the two acids do exactly the same chemical work is very interesting when we remember the different solubilities

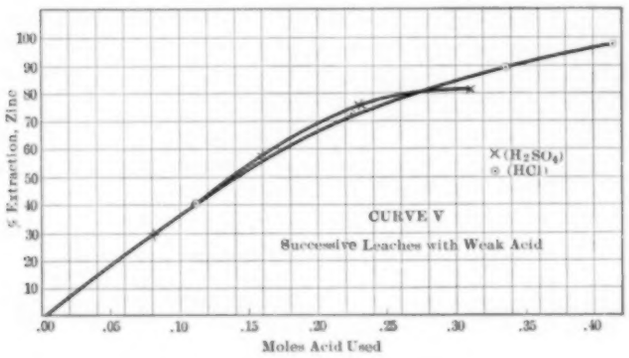


FIG. 5—EFFICIENCY CURVES

of $CaCl_2$ and $CaSO_4$ as well as the other factors which could cause differences in the amount of zinc dissolved in the presence of lime.

The individual efficiencies of each of these same leaches are shown in Curve IV, and rather than take averages of the duplicates, the four tests are plotted separately to show how nearly the duplicates check each other, and to give an idea of the reproducibility of the work. These curves could likewise be replotted with moles of acid as a unit instead of pounds of acid but we know from Curve V that they would fall very close to one another, and hence it is unnecessary.

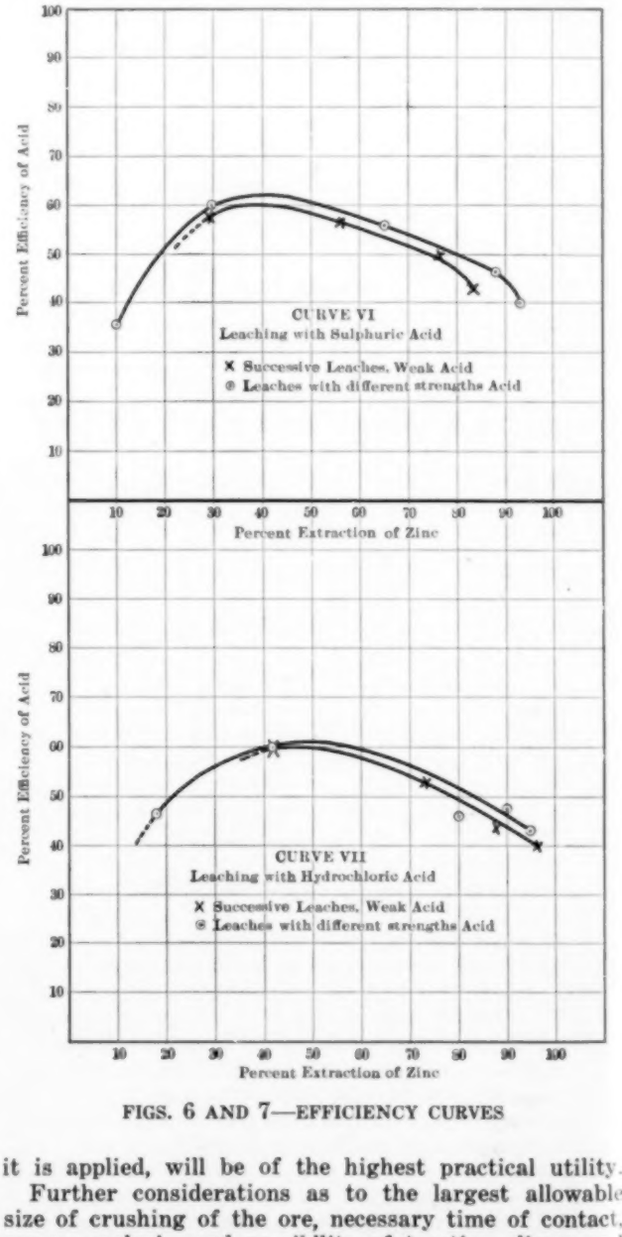
It is interesting in looking over this last series of tests to see that we check our former work of 60 per cent efficiency of acid when about 80 lbs. acid per ton of solution are added but that, as more and more zinc is extracted, the acid efficiency falls off. Suspecting that this drop in efficiency might be due to the same causes that made the higher strengths of acid less efficient, it was thought best to try to compare the tests of Series I with those of Series III by plotting the percentage extraction of the zinc for each experiment against the percentage efficiency of expenditure of the acid.

This is done in Curves VI and VII. The point marked by crosses and the curves drawn through them represent the results of the series of successive leaches with weak acid of the same strength in each leach, while the points marked by circles show the results of the separate tests with different strengths of acid.

The two sets of results seem to give curves that are practically identical. To express this fact we now have to say that as long as you take a certain amount of ore and treat it with a certain amount of acid, you get the same extraction of zinc and use up a certain percentage of the acid usefully, no matter if the acid be applied in one leach or if it is divided into a number of separate leaches.

Furthermore, as one curve is for a constant strength of acid and the other for different dilutions, and the curves are identical, we can say that no matter what the dilution a certain number of pounds of acid can extract only a certain percentage of the zinc and at only a certain percentage efficiency of expenditure of the acid. This result is of fundamental importance for it shows that no further experimenting with various strengths of acid need be tried on this particular ore and whatever the sizes of material employed a similar relation should be found.

Knowing then that we may use acid of any dilution that we please, as long as we get a sufficient quantity in contact with the ore to dissolve the desired quantity of zinc, the considerations which will determine the strength of acid to be used in mill solutions, will depend entirely on the mechanical point of view and different designers will have various opinions as to the best way to take advantage of this fact. So Curve VIII, giving the number of pounds of acid to extract any definite number of pounds of zinc (or to extract any definite percentage of zinc), no matter at what dilution



FIGS. 6 AND 7—EFFICIENCY CURVES

it is applied, will be of the highest practical utility.

Further considerations as to the largest allowable size of crushing of the ore, necessary time of contact, screen analysis, and possibllity of treating slimes and sands separately, as well as the possible influence of temperature on the inner relations and velocity of such leaches have not been investigated thoroughly yet, but the rather unusual turn of events met with in the

course of this series of tests seemed enough to warrant their publication.

Summary: A series of leaches with hydrochloric and sulphuric acids on a zinc lime ore has revealed that if insufficient acid to be added to dissolve the zinc, the efficiency of expenditure of the acid increases to a maximum of 63 per cent (the percentage which zinc forms to the total soluble material) but that further addition of acid to extract further zinc causes the efficiency of expenditure of the acid to fall off more and more to nearly 40 per cent when all the zinc is extracted. These figures are true for both acids.

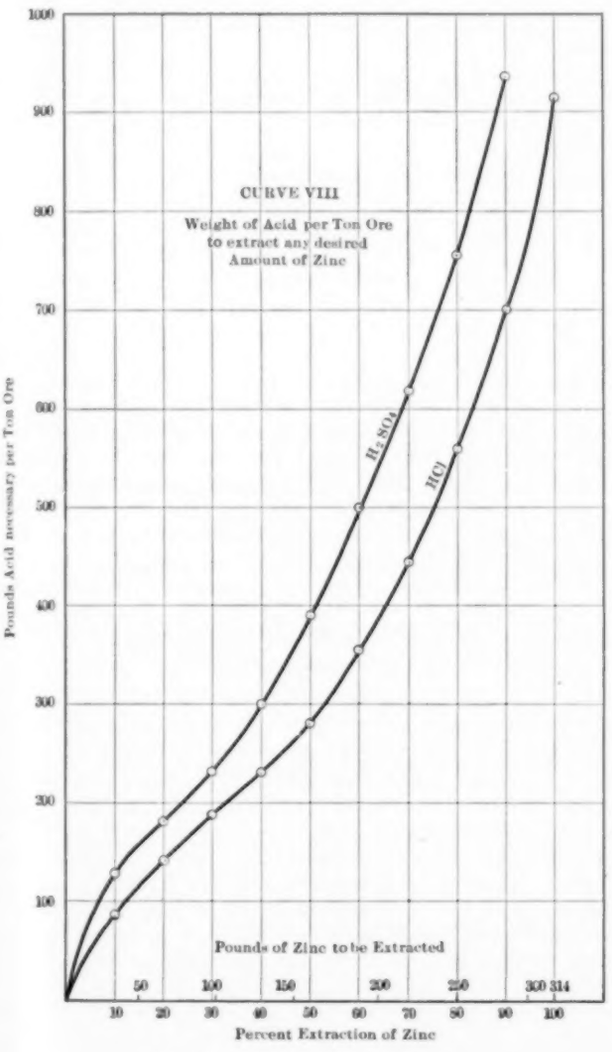


FIG. 8—EXTRACTION CURVES

Chemically, molecule for molecule, the two acids do exactly the same work, a result somewhat surprising in view of the solubility and other relations of the various salts formed. However, the higher chemical equivalent of a pound of hydrochloric acid would give it the commercial advantage of the same cost per pound.

The curious fact has been discovered that no matter at what concentration it is applied, a given amount of acid does the same work; hence the curve of the percentage extraction of zinc plotted against percentage acid efficiency, is the same for all strengths of acid.

It seems possible, by adding chlorine to the leaching solution to get a simultaneous extraction of both zinc and gold, though there is some question as to its desirability.

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The Determination of Manganese in Ferrovanadium

BY WILLIAM W. CLARK

The determination of manganese in ferrovanadium is not a serious problem as it can be determined by any one of several different methods, modified to suit the interfering elements present, and as the presence of manganese is not detrimental to steel, in which the majority of the alloy is used, the very accurate determination of it is not a commercial necessity.

Manganese which is added to ferrovanadium in percentages ranging from 0.25 per cent to 10 or 12 per cent has several beneficial properties. It enables the manufacturer to turn out an alloy, which is low in sulphur content, from an ore or oxide which contains considerable of that harmful element. To the user it offers several possibilities. It saves the heat in his steel when the ferrovanadium is added to the ladle, as manganese serves the double purpose of lowering the melting point of the alloy and of increasing its solubility in the molten steel. It saves the addition of a corresponding amount of manganese as ferromanganese, and it also increases the amount of vanadium recovered in the steel. As manganese has a greater heat of combination with oxygen than vanadium and will reduce vanadium oxide to the metal at the temperature of molten steel, it acts as a scavenger, which is more active than vanadium, and thus combines with some of the oxygen contained in the steel as oxides, which would otherwise be combined with and carried out by the vanadium.

The method for the determination of manganese in which the presence of vanadium interferes is the Ford-Williams method. In view of the fact that when a vanadium solution is boiled with strong nitric acid, vanadic acid separates, and also when chlorates are added, the liberation of chloric and chlorous acid precipitates vanadic acid from acid solutions almost completely, and as such a precipitate would be titrated as manganese, the method is useless.

The Volhard method can be used by observing certain precautions, mainly that of keeping the vanadium oxidized to its highest valency. This can be accomplished by using an excess of nitric acid, which will not interfere with the titration in any way, except in the presence of hydrochloric acid, which must be absent. The method in detail is:

The finely powdered alloy is dissolved in nitric-sulphuric acids, evaporated to small bulk, a few cc of concentrated nitric acid added, the solution boiled to remove all nitrous fumes, diluted, and almost neutralized with sodium carbonate solution. An excess of zinc oxide emulsion is then added and the solution is boiled for one minute. An aliquot portion can then be filtered off, over a dry paper and titrated, but it has been found that the presence of the precipitate in the solution is rather beneficial than harmful. The precipitate of vanadium and iron, which settles rapidly, envelops and carries down the slow-settling manganic oxide, thus saving time and making the end point sharper. There is a small correction factor to be determined, as it has been found that the theoretical factor will not give the actual content. This factor is determined by making a synthetic standard ferrovanadium from alloy free from manganese and a weighed portion of the Bureau of Standards manganese ore. Following are results obtained by this method:

The method using lead peroxide as an oxidizing agent could also be used but it requires a filtration which is objectionable, and it also demands the absence of sulphuric and hydrochloric acids, which are hard to remove, and the alloy breaks up with difficulty in nitric acid.

Manganese present Per cent	Manganese recovered Per cent
1.00	1.02
	1.03
	1.01
	1.00
	1.01
5.00	5.07
	5.02
	4.98
10.00	9.88
	9.92
	9.94

The method worked out by Dr. Cain using basic carbonates and oxides to precipitate the vanadium, free from manganese, and the manganese determined in the filtrate, can also be used and very good results are obtained, but it also has to be filtered. A slight modification of this method gives good results, and consists in reducing the vanadium by evaporation with hydrochloric acid, thus having the iron oxidized and the vanadium reduced, and then precipitating the iron and vanadium together, and determining the manganese in the filtrate.

The method which has been found to be the most accurate on all percentages of manganese found in commercial alloys is the persulphate method with the subsequent titration of the permanganic acid by sodium arsenite solution, which does not reduce the vanadium as does ferrous sulphate. The titration of the permanganic acid is always to be preferred instead of the comparison of the color with a standard of approximately the same percentage. The standard is not always available, and the yellow of the vanadium is not standard as different acidities give different tones, and what is of more importance, the titration is more accurate and can be done more quickly.

The method in detail is as follows:

0.2 gram of finely powdered alloy is dissolved in 10 cc of a nitric-sulphuric acid mixture (200 cc H_2SO_4, 200 cc HNO_3, and 400 cc H_2O) with the addition of a little hydrofluoric acid, if the alloy is refractory to these acids. The solution is vigorously boiled, diluted to 100 cc, 10 cc of a silver nitrate solution added (1.25 grams per liter) and an excess of solid ammonium persulphate. The solution is brought to a boil and cooled at once in cold water, a few drops of saturated solution of salt is added, and the manganese titrated to the disappearance of the last trace of pink. The operator can catch this point very exactly after a few trials, as the end point is very sharp and can be caught with one drop of the solution. In case the manganese content is above 5 per cent, the solution is diluted and an aliquot portion taken before adding the silver and persulphate. The general idea for this method is that it is not applicable for percentages above 1.5 or 2 per cent, but after using it for a number of years it has been found to be as accurate as any of the other methods on materials containing as high as 15 per cent manganese. The only precautions to be observed are that there must not be more than 0.01 gram manganese for each 100 cc of solution; chlorides must be absent and the acidity must not be too high. Larger amounts of manganese than above mentioned will cause a precipitate of manganic oxide in the solution, which does not titrate theoretically. Even with the above amount in case the acidity is too low, there is sometimes a precipitate, but it can generally be cleared up with a few drops of nitric acid.

The arsenite solution is made by dissolving sodium arsenite in water and standardizing against a standard ferrovanadium made from manganese free alloy and the Bureau of Standards manganese ore. The solution most used is standardized so that 1 cc will equal 0.05 per cent manganese on a 0.2-gram sample. The addition of the salt solution is also very necessary as it combines with the silver, rendering it quiescent. Otherwise the silver still being active as a catalytic agent, slowly reoxidizes the manganese during the titration, and while this is of no importance on a low value, on a high one, in view of the fact that the error so introduced is multiplied in accordance with the aliquot portion, it is considerable. The method is very rapid, taking only about fifteen minutes when the aliquot portion is not required, and then only a few minutes longer. Following are results obtained from this method, showing that it is possible to obtain concordant results commercially:

Manganese present Per cent	Manganese recovered Per cent
0.50	0.49
	0.48
	0.50
	0.51
	0.50
1.25	1.23
	1.24
	1.27
	1.22
	1.24
5.00	4.92
	4.94
	4.96
	4.94
10.00	9.90
	9.88
	9.92
	9.92
	9.90
15.00	14.96
	15.04
	15.06
	14.95

The determinations for the 0.50, 1.25, 5.00 and 10.00 were titrated with a solution standardized against the 0.50 per cent, while the 15 per cent was standardized against a 15.00 alloy. By using weighed burettes closer results might be obtained, but the above are close enough for any commercial purposes.

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The Purification of Boiler Feed Water

BY EVERARD BROWN

It is a well-known fact that the use of bad water for boiler feed purposes is not conducive to satisfactory and economical steam plant operation. It is also true that natural waters are hardly ever pure, no matter what their sources may be, and instances are indeed rare where the water is fit to be used for making steam without its receiving treatment of some kind either before or after its introduction into the boiler. Furthermore, there is a vast difference in the character of different waters, consequently each case must be studied and worked out by itself and the proper remedy prescribed. It is evident, therefore, that the elimination of impurities in the boiler-feed water and making it suitable for steaming purposes is one of the most difficult problems that confronts the engineer.

The various impurities in all waters may be divided into two general classes; namely, insoluble impurities, which can be removed by sedimentation or by filtration; and soluble impurities, which cannot be removed unless they are first thrown into suspension and then taken out by sedimentation or by filtration. While the insoluble or suspended impurities are a factor in considering the suitability of a water for boiler-feed purposes, nevertheless, they are of minor importance and can be taken out so easily that they need not here be further considered.

The most common of the soluble impurities, or those held in solution, are the following:

Magnesium sulphate, which is quite common in many waters and is extremely soluble. By itself it will not form scale, but it is easily broken up by lime salts from which scale is formed.

Calcium sulphate, also quite common in all natural

water supplies and which forms the hardest boiler scale. Furthermore, this salt will act as a cement, causing a hard scale formation with salts which ordinarily would form only a soft scale or sludge.

Calcium carbonate, which is only slightly soluble in pure water, but in the presence of carbonic acid dissolves in the water, forming bicarbonate of lime, which is soluble. Alone, however, bicarbonate of lime will not make a hard scale, but when present with other substances, which cement it, a hard scale is apt to result.

Magnesium carbonate is more soluble than calcium carbonate. It is usually found in water as bicarbonate of magnesia and has nearly all the characteristics of calcium bicarbonate.

Calcium chloride, which is very soluble and sometimes found in natural waters. In the absence of other scale-forming salts it is not injurious unless highly concentrated. After concentration in the boiler, however, it becomes dissociated and liberates hydrochloric acid, which, of course, is highly corrosive.

Magnesium chloride, a very objectionable salt because it both forms a scale and liberates hydrochloric acid.

Calcium nitrate, having practically the same characteristics as calcium chloride. Waters containing this salt are, however, comparatively rare.

Magnesium nitrate, usually present in only very small quantities and characteristically similar to magnesium chloride.

Sulphates of iron and alumina may be found in waters contaminated with the waste from galvanizing works or with mine drainage and, because of their dissociation by heat, sulphuric acid is given off and the iron or alumina precipitated as scale or sludge. These substances are very injurious in a boiler and cause corrosion the same as free sulphuric acid. The oxides of iron and alumina, on the other hand, while usually present in small quantities in nearly all waters, have but a slight bearing on scale formation.

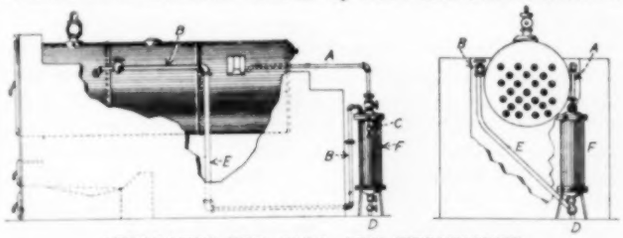
Sodium salts, that is, the sulphates, carbonates, nitrates and chlorides, are all neutral, do not form scale and are non-corrosive, consequently they are not objectionable unless present in large quantities. Silica may also be found in nearly all waters and, while it is a scale-forming substance, yet it is present only in such small quantities that it usually need not be considered.

In addition to all of the foregoing there is always some free carbonic acid in all natural, or raw, water which, of course, promotes corrosion in the boiler. This acid also holds in solution the calcium and magnesium carbonates. Also, if the water contains drainage from mines or galvanizing plants, there is sulphuric acid present in its free state which is extremely objectionable because it attacks the metal in the boiler immediately. This action forms iron sulphate which the heat in the boiler decomposes, resulting again in free sulphuric acid and iron hydrate. The liberated acid again attacks the metal and so goes through repeated cycles indefinitely. Since this acid is not volatile, its amount in the boiler is naturally increased continually by the quantity introduced with the feed water, so that it can easily be seen how the corrosive action multiplies in intensity and in direct ratio, as it were, with the concentration in the boiler.

The soluble-scale forming matter may also be divided into two general classes, those causing temporary hardness of the water and those causing permanent hardness. The former consists of the carbonates of lime, magnesia and iron. Their precipitation begins at temperatures approaching 212 deg. Fahr. and they can be entirely removed by boiling the water at atmospheric pressure for a short time. Permanent hardness is due to the sulphates, chlorides, and nitrates of lime, magnesia and iron which will not be precipitated at temperatures below the boiling point, consequently their removal together with that of the acids constitutes the real problem in water purification.

From the fact that a natural, or raw, water can contain such a large variety of impurities in varying quantities, it is evident that the problem is rather complicated and that each specific case must receive individual attention if the results are to be satisfactory. It should also be remembered that the characteristics of the impurities change under the different pressures and temperatures in the boiler and that their scale-forming properties are largely interdependent. Furthermore, the amount of scale formed does not always bear a direct relation to the amount of impurities in the feed water, but depends on the type of boiler and the rate at which it is operated as well as upon the nature of the impurities. Concentration in the boiler is another factor that enters into the question, since none but volatile matter passes out with the steam, consequently the non-volatile impurities gradually accumulate, forming varying quantitative relations with each other.

Although the scale formed in a boiler is the direct result of impurities in the water, yet an analysis of this scale is of practically no value in determining the character of the water from which the scale was deposited because of the fact that the scale is the precipitation resulting from reactions between some of the substances in solution as well as by heat and concentration.



APPARATUS FOR SODA ASH TREATMENT

Therefore, the original character of the impurities in the water is not always apparent in the scale.

In order to decide on the suitability of a water, or on its treatment for boiler feed purposes, it is essential that a careful and accurate analysis of it be made. This should be done by a chemist who makes a specialty of such analyses and who is thoroughly familiar with the characteristics of the water in relation to boiler operation. Unfortunately, however, this is not always done; or the remedy prescribed as a result of such analysis is not carried out. This is evidenced by the fact that scale is still prevalent in many boilers and that the manufacturers of tube cleaners, etc., are still busy making mechanical scale removers. Moreover, there are many compounds as well as mechanical contrivances on the market that are guaranteed (?) to prevent scale formation in the boiler, no matter what kind of water is used. Some of these may be efficacious under certain conditions and with certain waters, but as a general cure-all they are an absolute failure.

Use of Boiler Compounds

One quite prevalent method of preventing scale, or rather trying to, is by the use of boiler compounds, some of which act chemically and others mechanically. Kerosene and crude oil are also sometimes used, but to a much less extent. Graphite is the most common material which acts mechanically and its purpose is to give the interior of the boiler a thin coating which will prevent the adherence of the scale-forming matter to the shell and tubes. It seems, however, that its efficacy under all conditions and for all kinds of water is a matter for honest debate. The compounds which act chemi-

cally usually consist of sodium carbonate in combination with some organic acid such as acetic or tannic.

While it is true that in certain specific instances the use of a boiler compound has prevented, or at least reduced, the formation of scale, nevertheless, in order to obtain such results it is essential that the quality and quantity of the compound should be specially adapted to the particular water in which it is used. This makes it extremely difficult to use a compound successfully because of the variable quality of feed waters and the large variation in the amount of water fed into the boiler. As a rule, however, boiler compounds are quite effective in overcoming corrosion because they are usually alkaline in nature and, therefore, neutralize the acids. On the other hand, extreme care should be exercised in using a compound for this purpose because many of them contain corroding agents and consequently are in themselves the cause of corrosion.

Aside from acting as a neutralizing agent for acids, the only function of a compound is to change the nature of the precipitate from one which adheres to the surfaces of the boiler to one which will be carried in suspension in the water. The result is a muddy, insoluble mass made up from the impurities already in the water plus the ingredients in the compound itself. This naturally increases the density of the water and consequently its boiling point is raised because of the fact that the soluble impurities are constantly increased by the concentration resulting from the evaporation of only pure water. This action makes of the boiler simply a catch-all or accumulator for the foreign matter. Furthermore, this accumulation of sludge cannot be entirely removed by blowing off, therefore frequent washing out becomes a necessity. In brief, it may be said that the use of boiler compounds is an attack on the result rather than on the cause and as such should only be followed when no better means of treating the water is practicable.

Soda Ash Treatment Within the Boiler

There is another method of treating boiler feed water on the market which is similar in principle to the use of boiler compounds in that the water is treated after its introduction into the boiler. This system goes a step further, however, and employs a filter to remove from the boiler water all the impurities held in suspension. In other words, it is a combination of chemical treatment and mechanical filtration. Reference to Figs. 1 and 2 will show the principle by which this is accomplished.

Soda ash is first introduced into the boiler in sufficient quantities to throw into suspension all the soluble impurities contained in the water. The water containing this suspended foreign matter is then drawn off through the pipe A and carried down through the center of the filter F which has a collecting space at the bottom. It is then forced upward through a crushed granite filtering medium and returned to the boiler as pure water through the pipes B and E. The Pipe E, which acts as a circulating pipe also, is considerably larger than any of the other connections and is so located in the boiler furnace as to be exposed to the greatest heat, the idea being that the circulation set up in this manner will cause sufficient suction through the apparatus to draw off the suspended matter from all parts of the boiler. To clean the filter the blow-off valves D are opened and the valve on the "draw-off" pipe A is closed. This releases the steam pressure through the return pipes B and E and reverses the flow through the filter, thus removing the collected sludge, etc., from the filter. C is a small vent to free the filter from steam after blowing out. The location of the connections of pipes A and B to the boiler are of no special importance except that they must be below the flue level so as to be entirely submerged.

It would seem that a considerable loss of heat would be entailed by the use of this system of water purification, both from radiation and from the loss of the heated water blown out through the blow-off valves. In fact, a loss by radiation is practically admitted by the manufacturers of the apparatus because the assertion is made that a lower temperature in the filter materially assists precipitation, which is completely effected in the upward movement of the water through the filtering medium. That a loss results from blowing out some of the heated water every time the filter is cleaned is, of course, self evident. Furthermore, while this apparatus, if it performs the functions intended, will prevent concentration in the boiler, yet the same objections to it might be raised that apply to the use of boiler compounds; namely, it is not good practice to do the purifying within the boiler itself because of its interference with the business of making steam. Any advantages it might have lie in its cheapness, small floor space required, low operating cost, etc.

A Physiochemical Action

Perhaps the most remarkable and startling novelty in the way of a feed water purifier is what is called a "Luminator." It consists simply of an aluminum plate of specific dimensions and having corrugations thereon of a particular size, both of which are determined by the character of the water to be treated. The treatment is merely allowing the water to run over this plate. It seems that a current of electricity is induced by the passage of the water at certain speeds over the plate and, the water being negative and the plate positive, ionization of the salts takes place. These do not take a crystalline form but become amorphous. It seems there is also another action which takes place; namely, aluminum is by friction and electrical action abraded from the surface of the plate as a colloid, which, after a period of time, also undergoes a change in the water. These remarkable changes are all brought about without the aid of chemicals of any kind, the whole process being called purely "physiochemical."

Professor Donnon at the Liverpool University, England, has investigated this process, it seems, and has found that aluminum hydroxide was not present to any appreciable extent in the water treated by this method; but he did find that the aluminum was in a collodial form mixed with hydroxide and remained so for several days after treatment. Reports further seem to indicate that the best results are obtained when the so-called "luminator" is facing either north or south and is exposed to direct light! Also that if shut in completely from light and air it becomes almost inoperative. The professor assumes that the earth's magnetism has some effect on the operation of the plate and that if its plane is set so that the earth's magnetic field crosses it there will be produced a small electromotive force at right angles to the grooves of the plate as the water flows down, resulting in a slight electrolytic action and thus precipitating aluminum hydroxide in the solution. He also says that the local electricity, together with a certain amount of chemical action, due to the heterogeneous nature of the metal, are sufficient to explain the surprising and hitherto unknown disintegration of the aluminum. That this explanation is quite clear is more than doubtful.

The foregoing would indicate that boiler troubles resulting from scale formation could be overcome by the simple expedient of installing an aluminum plate and passing the feed water over it. There must be, however, certain limitations to the efficacy of this method of water purification. For example, water containing ferrous sulphate, or large quantities of iron in any form, are

not susceptible to such treatment because of the continual deposit of iron on the plate.

Likewise, any acid in the water will not be neutralized, such water requiring a preliminary treatment by passing it over marble or chalk in order to get the desired result. Furthermore, if the "luminator" is at some distance from the boiler it is necessary that the water mains, etc., be coated with a non-conducting composition, such as bituminous varnish, and that the water reach the boiler as soon after treatment as possible. The statement is also made that where the apparatus is used continuously night and day it is advisable to give it a rest of one day per week, otherwise the plate may become "polarized." It is rather difficult to reconcile this statement with the one stating that the plate must be exposed to light to be effective. If the latter is true how can it be used both day and night?

Assuming that this aluminum plate will do the things that are claimed for it, the question is: What becomes of the various impurities contained in the water? In reply to this we are told that the various salts in the raw water before and after treatment show, upon analysis, the same chemical composition; that the sulphates and carbonates of calcium, as well as the magnesium salts, remain as before; and that only a physical change takes place. In a boiler this change is supposed to take place immediately, thus preventing the salts from again going back from the amorphous to the crystalline form, consequently they are deposited as a powder.

This supposed action of the "luminator" and the consequent results obtained therefrom may, perhaps, be quite clear to the inventors, but to the writer it certainly savors of mystery and magic. In other words, this "luminous" treatment of water is not very illuminating and the claims supporting it are far from convincing. At all events there will no doubt be considerable "missionary" work required before it receives anything but the most skeptical consideration.

Water Heater-Purifiers

One of the common methods of attacking the problem of scale formation in the boiler is by pre-heating the feed water. This method is based on the well-known fact that raising the temperature of water reduces the solubility of some of the salts in solution. The apparatus used for this purpose is the "feed-water heater and purifier," and is designed to receive the deposition of the scale-forming substance instead of letting them enter the boiler itself. That it will fulfill this purpose to some extent is unquestionably true, but whether it completely solves the problem or not is rather doubtful.

There are two kinds of heater-purifiers on the market, both of which are supposed to intercept the impurities in the water. One is the open or exhaust steam heater into which only exhaust or low-pressure steam is introduced to heat the water, and the other is the closed or live-steam heater in which steam at boiler pressure is used. In the first, of course, the temperature of the water cannot be raised to more than 212 deg. Fahr., the boiling point of water at atmospheric pressure. It is also obvious that in this type of heater only the temporary hardness of the water will be effected and that only partially, because precipitation is a gradual rather than an instantaneous process and the length of time the water is usually allowed to remain in the heater is not sufficient to make the precipitation complete. To overcome this difficulty the size of the apparatus has lately been increased so as to allow the water to remain longer; and in some instances softening reagents have been introduced and a filtering device attached. These steps taken by the manufacturers are an indication that the old type of open, exhaust heater-purifier does not fully meet the requirements.

The closed type, or live-steam apparatus, on the other hand, will remove practically all of the temporary hardness but not all of the permanent hardness. While it carries practically the same pressure and temperature as the boiler, yet to precipitate calcium sulphate, for example, a certain amount of concentration is necessary in spite of the general assumption that this salt is insoluble at temperatures above 300 deg. Fahr.

The real function of a heater is to heat the feed water and as such both types are very successful. As a purifier, however, it does not quite come up to requirements, although it must be given credit for doing some good. In the same sense that a feed-water heater is also a purifier so might the boiler be called a purifier because scale deposits in both. Aside from heating the water, the advantage in the heater is that this deposit is more easily removed than from the boiler, provided, however, it entirely purifies the water so there will be no deposition at all in the boiler.

Chemical Water Softening Systems

Any method or apparatus for softening and purifying water in a satisfactory manner must be such that the acid contained will either be eliminated or neutralized; the permanent hardness removed and any remaining scale-forming substances reduced to a negligible quantity. It must also produce a clear effluent. If these results are not obtained, then the method employed is either wrong in theory or application, or the apparatus is faulty in design or operation or both. Of course, to properly treat water is a rather delicate process, more so perhaps than might be generally believed. This is because of the small relation the amount of impurities, which have to be removed, bears to the volume of water to be treated. Therefore, to get results, an accurate analysis of the water is of prime importance for determining the treatment and the apparatus required.

Without doubt the most satisfactory and efficient manner of treating feed water is by means of proper reagents in exact quantities to react with the impurities, followed by the complete clarification of the water by sedimentation and filtration. The apparatus on the market that operates on this principle is commonly called a "water softening and purifying system." There are two types of this apparatus, one called the continuous and the other called the intermittent. Either one will produce good results if given proper attention.

In the continuous system the reagents are introduced by proportional feed devices, usually actuated by the water entering the system. The water enters either at the top or bottom and flows out by displacement at the same rate at which it enters. An adjustment must, therefore, be made in the quantity of reagents introduced in order to meet every variation or change in the water. Unless this matter of adjustment is watched carefully there probably will be times when the water is overtreated and other times when it is undertreated.

In the intermittent type, on the other hand, the water is always treated in measured quantities, and the exact quantities of reagents required are weighed out; therefore, any water can be treated most accurately, no matter how it may vary in quality or quantity. But, as compared with the continuous system, it requires much more ground area, more expansive foundations, and possibly a little more labor to operate.

However, it is not the intention to weigh the advantages, or otherwise, of the one system against those of the other, because, as said before, if properly attended to, either one will give results, as attested by the fact that there are a great many of both kinds not only in use but also are being sold at the present time.

As a general rule the reduction of the scale-forming impurities to 5 grains per United States gallon and the

elimination of the acids is considered good practice. There are, however, cases where it has been found necessary to reduce the scale-forming substances to less than 3 grains to prevent scale, and others where good results are obtained with as high as 6 to 7 grains. It is impossible, of course, to remove all of the substances, as calcium carbonate and magnesium hydrate are slightly soluble at all times. Nor is it possible to take out any sodium salts except by distillation, because they are all soluble and no chemical treatment will throw them into suspension. In properly treated water, however, they do no harm to the boiler as they are neutral, non-corrosive, and non-scaling.

The reagents commonly used in these water-softening systems are lime and soda ash, although other substances are sometimes used, depending upon the nature of the water. The cost of purifying will, of course, depend upon the amount of reagents required, for it is readily understood that it will require more chemicals to remove 30 grains of some impurity than it will to remove 10 grains. Almost any expense, however, incidental to the proper softening and purifying of water for boiler feed purposes is more than offset by the savings that result.

In conclusion it might be observed that the limit of possible economy is much more distant in the boiler house than in the engine room and that the first essential in economy of boiler operation is that the water should be of a quality which will permit of the utilization of the greatest number of heat units in the fuel, at a minimum cost of boiler maintenance. In many steam plants may be found the most improved design of boilers, with mechanical stokers, stack dampers, feed-water regulators, feed-water heaters or economizers, and no doubt the most economical prime mover obtainable in the engine room; but the matter of pure water is often totally neglected.

Electric Smoke and Fume Precipitation Before the American Institute of Electrical Engineers

The morning session of Friday, February 19, 1915, of the Midwinter Convention of the American Institute of Electrical Engineers was devoted to a symposium of papers on electrostatic fume and smoke precipitation. The large lecture hall of the United Engineering Societies Building was filled. Many members of the American Institute of Mining Engineers were present, following a cordial invitation extended to them. President P. M. Lincoln of the American Institute of Electrical Engineers presided.

The first paper was presented by Dr. Frederick G. Cottrell who gave a very full and detailed historical sketch of electrostatic fume precipitation, starting with a German text book note of 1824, but dealing naturally in greater detail with the work of Sir Oliver Lodge, and then sketching his work which led Cottrell, jointly with O'Neill, Heller and Miller to the formation of the Research Corporation (see our February issue, pages 81 to 84). Work along similar lines, under the direction of the late Robert Kennedy Duncan, of the Mellon Institute, was also noted and Dr. Cottrell was glad to state that a method of coöperation between the Research Corporation and the Mellon Institute had been effected.

The electrostatic precipitation process is naturally suited to solve two problems: first, the precipitation of man-made fumes (smelter fumes, smoke from boiler furnaces and the like), and second, the precipitation of fog, in the open atmosphere. Sir Oliver Lodge had been specially interested in the second problem. Dr. Cottrell had so far worked only on the first problem, as there was enough trouble to be overcome in its special field and the second problem is better attacked after the first one is solved. Now the San Francisco Exposition seems to offer possibilities of experiments on the second problem and shipping interests have become quite interested in the possibility of using Cottrell apparatus in front of a vessel to dispel fog and prevent accidents.

The second paper of the session was presented by Dr. W. W. Strong, of the Mellon Institute of Industrial Research, on "the theory of the removal of suspended matter from fluids."

The frictional resistance of a small particle moving through a fluid is given by the law of Stokes. Knowing the density and size of the particles and the coefficient of viscosity of the medium, the amount of energy required to remove suspended matter from fluids can be calculated. From the formulas the relative efficiencies of the different methods used to remove suspended matter from gases can be obtained. From these formulas the electrical method is shown to be especially adapted to fine suspended particles or to a mixture of gases that can be selectively ionized. In a practical case of electrical precipitation of smoke it is shown that approximately 4 per cent of the energy of the corona discharge is actually expended in the process of precipitation.

The manner of the distribution of the energy of the corona discharge is discussed. The nature of the corona ionization and the "corona" rays is also briefly described.

The application of the theory of electrical precipitation is given so that it is possible to determine the best working conditions for precipitating a given kind of suspended matter from a given fluid. The theory also indicates the limits of usefulness of the method of electrical precipitation.

Dr. Strong showed at the conclusion of his paper a number of lantern slides and moving pictures.

Professor A. F. Nesbit, of the University of Pittsburgh, followed with a paper on "the theoretical and experimental consideration of electrical precipitation," also illustrated by lantern slides.

Mr. Linn Bradley presented the last paper of the session on "practical applications of electrical precipitation and progress of the Research Corporation."

The technical and financial progress made by the Research Corporation since its organization in 1912 is given, and several plants are described. Voltages, electrode spacings, power consumption, etc., are given for several installations. Mention is made of a number of improvements in the electrical apparatus and means for its control. Progress has been made towards standardization of apparatus for this work.

The paper is illustrated with reproductions from photographs of installations in various stages of operation. Curves and charts show the peculiar character of the circuit, the method of obtaining data to be used in designing treaters and of conducting tests. Alternating current of 250,000 volts has been rectified and used for precipitating particles from gases. Fumes have been separated into fractions by means of temperature control and the electric process.

A selected bibliography is included. The statement is made that within three years time the original capital of $10,100 has been paid back to the stockholders, and that a fund of over $150,000 has been accumulated from the corporation's work, to be used for scientific research.

After the conclusion of the paper Mr. Bradley showed lantern slides and moving pictures of Cottrell plants in actual practice and finally demonstrated experimentally the Cottrell process for fume precipitation. The demonstration was very successful, the smoke being instantaneously stopped by closing the circuit of the Cottrell apparatus, and appearing again quickly when the circuit was opened.

In the discussions which followed Messrs. Franklin, Bradley, Dushman, Nesbit and Job participated. Of particular interest was the statement of Dr. Dushman of the General Electric Company that a very simple rectifier had been evolved on Dr. Langmuir's principle that the electron emission from a hot filament in a high vacuum is unidirectional. Professor Nesbit confirmed that this rectifier type, which is of very small size, works very well for smoke precipitation.

Filling the Blast Furnace

BY J. E. JOHNSON, JR.

This is the most important single operation of the whole blast furnace process. The details by which it was carried on in early years are quite unknown to me. The earliest system of which I have knowledge consisted in throwing into the open furnace top the ore and limestone from large wheelbarrows, while the charcoal was thrown in from baskets made for that purpose, these baskets being elliptical in shape, about 4 ft. long, by 2½ ft. wide by 1 ft. deep, with hand-holds at each end. When mineral fuel was used it also was handled in wheelbarrows and even before the introduction of the closed top the use of "filling barrows" became almost universal except at charcoal furnaces. These barrows

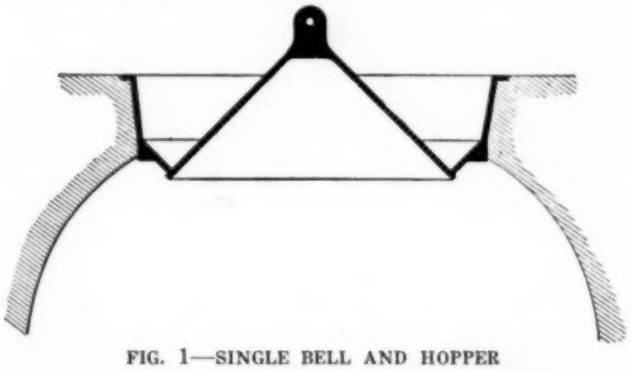


FIG. 1—SINGLE BELL AND HOPPER

(Distributes the charge in a ring next to the lining.)

are the two-wheeled type illustrated in the second article of this series.

The first method adopted for closing the top of the blast furnace was the one which has remained in use practically ever since. The apparatus is known as the "bell and hopper." In its simplest form it is illustrated by Fig. 1. It consists of an inverted cone forming a hopper set on, or in modern practice, fastened to the top of the furnace, the opening of the hopper being closed by a cone which sometimes has a rounded top and from its general shape it takes its name, the "bell." The bottom edge of the hopper is turned true in a boring mill as is the lower portion of the surface of the bell, so that they make a good fit. Into the annular space of triangular section formed by these two, the charge is dumped, by tipping forward the barrows on their own axles as a center, and when the bell is lowered the charge slides into the furnace through the annular opening formed.

During the long period in which the furnace approximated to its modern development, and ending with the Duquesne revolution, this method of filling was almost universal. The quantity of labor it involved was well recognized, and many efforts had been made to avoid this by the introduction of mechanical methods of charging. But these so almost universally had a highly detrimental effect on the operation of the furnace that they were in earlier times soon abandoned for the time-tried method universally known as "hand-filling."

It seems at first sight absurd that so simple a matter should be so obscure and should involve such great difficulties. But the spacing of the stock on the bell, the dumping of the barrows at the edge of the hopper, or on the apex of the bell, the size of the charge, and whether the ore and stone should be dumped with the coke, or separately, are all questions which may exercise an influence on the working and economy of the furnace so great as to be literally vital.

This is a field in which we have little or no theory to guide us. Our information comes solely from tedious and expensive empirical methods better described as "trial and error." Our knowledge of what constitutes correct filling comes solely from our observation as to how furnaces work with different types of distribution, and while the whole history of this vast subject abounds in contradictory experiences in the failure of apparatus and methods of operation at one plant which have made a brilliant success at another, and in other facts difficult or impossible to reconcile with one another, certain laws stand out as established by experience so nearly universal that I believe no one will question them.

These laws are: First—The distribution of each kind of stock in the furnace must be symmetrical, about not less than two axes making equal angles with each other. Second—The same proportion of lump and fine must obtain in each of the segments into which the circle of the top is cut by these equally spaced axes. Third—The distribution of fine and coarse material radially must be such as to produce as nearly as possible an equal ascent of gas through each portion of the furnace stack. To these must be added in some cases, if not in all, a fourth—The stock should be distributed not in uniform annular rings around the hopper, but in heaps, equally spaced around it.

In further explanation of the first law it may be said, on the authority of many trials, that it is not sufficient to dump all the stock symmetrically on one diameter of the furnace. No matter how carefully it may be spaced along that diameter, or even if it be dumped by tipping to first one side and then the other of the diameter, the results are unsatisfactory. This is for the reason that the tendency of this method of filling is to make two or perhaps three flat columns of coarse material separated by one or two flat columns of fines as indicated in Figs. 2 and 3, and the gas travels so much more freely through the coarse material that this descends much more rapidly than the fine, and reaches the hearth in an unreduced condition, or perhaps the opposite action takes place, and the gas being unable to penetrate the columns of fine material, does not reduce it adequately, so that it reaches the hearth improperly reduced. At all events one portion of the stock is reduced ahead of the other and the quantity of fuel which must be burned in the hearth is that required by the least reduced portion, which therefore controls the economy of the furnace. We must, therefore, dump the stock on two axes at right angles, three at 60 deg. apart, or four at 45 deg.

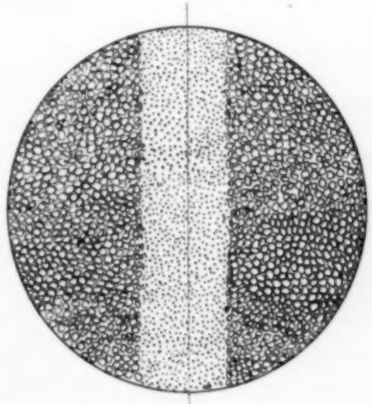


FIG. 2—SKETCH OF DISTRIBUTION OF CHARGE



FIG. 3—SKETCH OF DISTRIBUTION OF CHARGE

When hand-filling is used it is quite easy to secure compliance with all four of the laws above stated. By dumping at four or six symmetrically placed points around the hopper, with barrows of the same sort of material, we comply with the first two laws. By the proper adjustment of the size of the bell to the diameter of the stock-line we comply with the third, and the essence of the system involves compliance with the fourth, that is, dumping in heaps symmetrically placed around the bell.

Hand-filling requires that top-fillers be carefully trained to their work, and that some pains be taken to see that they do not dump all the material on the side next to the hoist or otherwise incorrectly. This is a grave temptation to them when the furnace is driving rapidly, and they are pushed to keep up. Their succumbing to this temptation has been the ruination of more than one furnace manager who could not catch them at this trick, or stop them from it; because nothing will more quickly and completely ruin the successful operation of the furnace than filling on one side or irregularly in any way.

Even though the top fillers are well trained and faithful, there remain certain precautions to be taken even with this simple and easy system of filling. The necessity for these arises from two causes. First, the distribution and shape of the four heaps on the bell, if they are dumped consecutively, is not all alike by any means. Second, the charges are practically never made up of a number of barrows of each material divisible by the number of dumping points. That is to say, we may easily have four or six barrows of coke to the charge, to suit the number of dumping point, but this having been determined we must have a number of barrows of different kinds of ore and of limestone, depending upon the weight of the coke charge so established, and these numbers will not commonly, in fact seldom or never, be similarly divisible by four or six as the case may be, if there are twelve barrows in the round.

The lack of symmetry of the different heaps in the hopper when dumped consecutively is due to the fact that the first barrow dumped striking the hopper when it is perfectly empty spreads out laterally in both directions. The second one dumped on the diameter at right angles to it, endeavors to do the same, but the pile which it tends to make is stopped from spreading toward the first barrow dumped by the pile which the latter has formed. Consequently the contents of the second barrow spread freely on one side, but much less freely on the other. Thus the center of gravity of its contents does not lie in its dumping plane, but is deflected away from the first dumping point. The action in the case of the third barrow dumped is exactly the same, it in turn is forced around by the pre-existing heap from the second barrow. When we come to the fourth barrow the space into which it would naturally spread out laterally is cut off on one side by the heap from the first barrow, and on the other side by the heap from the third, with the result that this heap is very generally higher and always much narrower than that from any of the other barrows.

Instead of having a circle divided into four equal parts of 90 deg. each, we have the first of 100 deg., the second of 90 deg., the third of 90 deg., and the fourth of 80 deg., or some similar arrangement. This, of course, lacks very much of being the ideal symmetry which is required not only by theory, but rigorously demanded by the results of practice.

To overcome this lack of symmetry and also that due to the fact that the total number of barrows in a charge is frequently not divisible by the number of dumping points around the hopper, we have a simple means not as universally followed as it should be. This consists in shifting the first point on the bell one space each time. A very easy method of accomplishing this result is to have a number of barrows, one more or one less than an even multiple of the number of barrows in the charge. Then if pains be taken to see that the fillers go round the top always in the same direction, the first barrow dumped on each charge will always be one space away from where it was the last charge On the next, another space, and so on until within a comparatively few charges the circuit has been made, and the first barrow comes back to its starting point. This means that while each individual charge lacks much of symmetry, its initial point is revolved so that each portion of the furnace in turn receives the same treatment, thus producing what is known as "spiral filling," since any given point, such as the dumping point of the first barrow, in the successive charges as they descend through the furnace, makes a series of steps very similar to those of a "spiral" (helical) staircase.

How old this method of filling may be I do not know, it was first called to public attention in a paper before the American Institute of Mining Engineers by W. A. Barrows, then at Sharpsville, Pennsylvania, about ten years ago. On account of the important irregularities in any one charge whose origin I have tried briefly to describe, this or some similar system giving analogous results, should always be used in hand-filling.

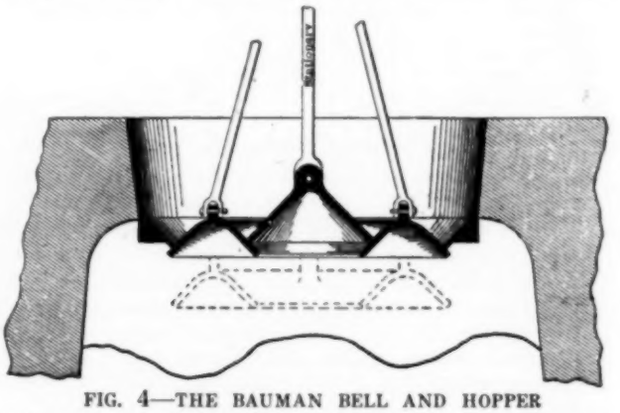


FIG. 4—THE BAUMAN BELL AND HOPPER

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

When two top-fillers are employed another system can be employed with good results. This consists in having the two men dump their barrows at points immediately opposite one another, and at the same instant. The next time they dump opposite to each other again, but in the case of 4-point dumping this, of course, means, at right angles to the first position. The two pairs of heaps so produced are not similar but each one is similar to its opposite, and by alternating the position for the first dump the series of charges formed are all symmetrical about two axes, although the heaps on one axis are not like those on another, but these are alternated so that in the course of a double charge we even up the inequalities of one charge with those of the next. It is more difficult to secure this sort of filling than it is spiral filling, and this kind should not be used in preference to that except under unusual circumstances.

The size of the charge unit to be used, and whether the coke and ore are to be dumped all at once or separately are questions of operation rather than of construction, and will therefore not be discussed here. But in a general way we may say that coke charges range from six thousand pounds for small furnaces, up to fifteen thousand, and even eighteen thousand pounds on larger ones, while the best practice undoubtedly favors dumping the coke separately from the ore and stone.

Similarly the question of the diameter of the bell which controls the radial distribution of the stock is a question of operation, and not one of construction, since the same construction is used in both cases, with only a relative slight difference in dimensions, and this question can therefore be passed over here.

Many modifications of the bell have been made with the object of securing better distribution and better furnace work. These have sometimes been only changes in dimensions, but many other variations have been used as well. A number of these are shown in Figs. 1, 4, 5, 6, 7, 8, 9, taken from a paper by the late T. F. Whitherbee before the American Institute of Mining Engineers, vol. XXXV, entitled "Special Forms of Blast Furnace Charging Apparatus."

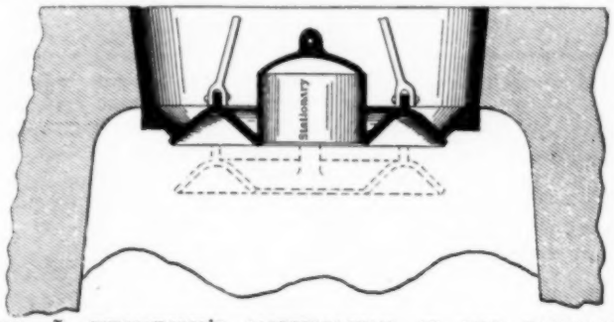


FIG. 5—FIRMSTONE'S MODIFICATION OF THE BAUMAN BELL AND HOPPER

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

Fig. 7 is representative of a number of these, this being the Firmstone modification of the Bauman or double bell. The center of the cone forming the ordinary bell is cut away by an inverted cone having the same angle of slope as the bell, normally 45 deg., and the opening so formed is closed by a (nearly) stationary part commonly called by those who use this type of top, the "plug." This is not quite stationary for the reason that the inner and outer surfaces of the bell must both make a good joint. It would be impossible to maintain an adjustment of the parts which would secure this if both seats were rigid, so the plug is counterweighted until its effective weight is very small and allowed a drop of about a half or three quarters of an inch, which permits it to follow the bell down for this distance on the opening movement, while on the closing movement the bell picks it up and makes the joint on its inner seat first, then reaches its seat on the outer surface or hopper afterwards, carrying with it the plug through the distance the latter dropped in opening.

Fig. 7 differs from the other types shown in that the gas outlet takes place through it, there being no flues in the side walls of the furnace. This secures an absolutely symmetrical distribution of the gas as well as of the stock, and while the former is less important than the latter, it is still very important.

Tight joints in the pipe are maintained in spite of the rise and fall of the center plug by ball joints at each end of the horizontal pipe shown broken off at the left hand side of Fig. 7. The ball joint not shown is at the top of the down-comer over the side of the furnace,

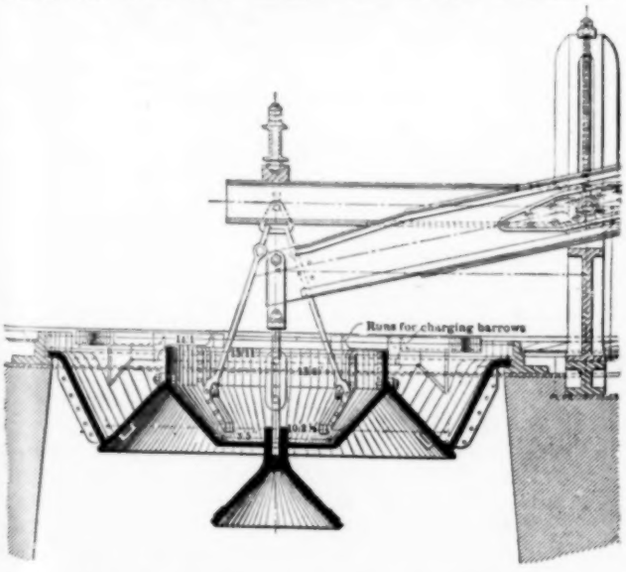


FIG. 6—THE DURHAM BELL AND HOPPER

(Distributes the charge in three ways: 1. In a large ring next to the furnace lining. 2. In a small ring. 3. In both a large and a small ring.)

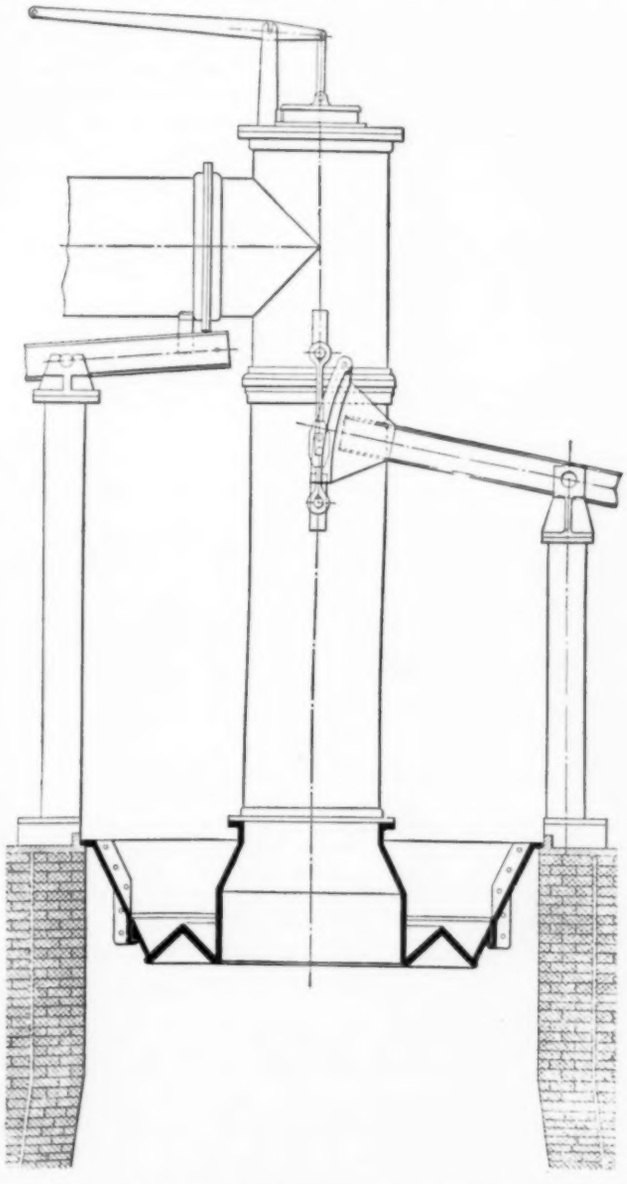


FIG. 7—THE BAUMAN-FIRMSTONE BELL AND HOPPER AT THE LONGDALE

(Distributes the charge both in a ring next to the lining and in a central heap smaller than that shown in Fig. 8.)

while the one in the vertical center pipe is shown at the bottom of the "tee" which forms the junction between the vertical and horizontal pipes. The small amount of vertical movement necessary in the center pipe is taken up by these ball joints without any difficulty. The center pipe, with the plug fastened to it, is suspended from the tee by turn buckles, of which the one on the near side is clearly shown in the illustration.

In this type of top the lever which supports the bell can of course not be located in the center, and is therefore made double and takes hold of the bell at four points. See Fig. 10 which shows the construction used in Fig. 7 also. This type of top was used at the plant of the Longdale Iron Company practically throughout its entire life, and combined with careful hand filling gave excellent results. The great advantage of the double bell over the single is that there are two openings of different diameters, which combined with the reversed

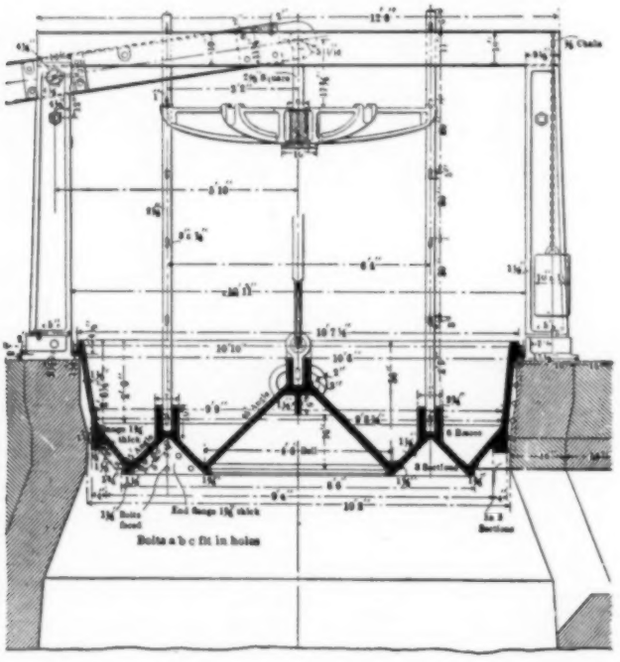


FIG. 8—BAUMAN DOUBLE BELL AND HOPPER AT THE SAUCON FURNACE, HELLERTOWN, PA.

(Distributes the charge both in a ring next to the lining and in a heap at the center.)

slopes inside and outside the bell permit the stock to be distributed more advantageously in the furnace than is possible under certain conditions with the single bell. The latter is confined to a maximum of three circular annular areas of different sizes of material, and may give only two, whereas with the double bell there can be two rings of fines, and three of coarse material, thus permitting a better distribution of the gases over the whole area of the furnace, and exposing the stock to this influence much more effectively.

This top has been used at many other plants beside Longdale, and has been very generally commended by those who have used it, but it is undoubtedly somewhat more complicated than the single bell top, and that, with the extreme difficulty of proving the advantage of one or another method of distribution on the furnace unless one of those under consideration be very bad, has prevented its general adoption.

A still more radical departure from the standard single bell top is the Langen charger in which a central piece like a plug rests in the bottom of the hopper to close it instead of being pulled up from beneath as in the standard type. The "bell," which is still so called in this case, is raised, to open it, instead of being lowered as is the regular bell. Frank Firmstone developed the double Langen charger in which the discharge took place around circles of two different diameters as in the Longdale double bell, but both openings were produced by raising the closing-pieces or bells, first one and then the other. He has described this top as applied by him at the plant of the Glendon Iron Company in the transactions of the American Institute of Mining Engineers, Vol. XIII.

The top is well shown by Fig. 10, reproduced from this paper.

Excellent results were secured with these bells, but more care and skill was necessary in designing and operating them than for the ordinary single bell, and they have never had a wide use in this country, although bells of this type are still extensively used in Germany.

There is one important difference in the conditions under which these tops had their principal use and those which predominate to-day. This is in the size of the ore, which in those times was almost entirely lump com-

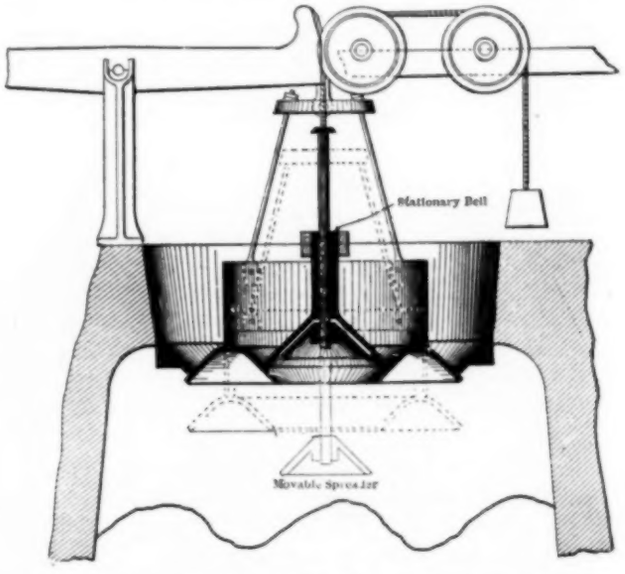


FIG. 9—THE WITHERBEE DOUBLE BELL AND HOPPER

(Five ways of distributing the charge: 1. A ring next to lining. 2. A center heap. 3. A ring next to lining and a center heap. With spreader bell down. 4. A large and a small ring. 5. A small ring.)

parable in size with the fuel, while now the ore is almost exclusively fine.

In order to have the gas travel uniformly through the stock it is very important to have the greater portion of the fines next to the walls since with *material of uniform size* the spaces next to the wall are about twice as great in proportion as they are in the body of the material, because when the high points of the individual pieces interlock with one another as they do in the mass of the material the interstices are very largely filled, but when the high points come against a flat surface the interstices are preserved complete.

By taking spheres we can determine the amount of interstices under each condition. We find that if there be a layer of spheres of uniform size arranged in close contact in equilateral triangles (the closest possible spacing) with another layer of like spheres resting in the low points of the first as they would arrange themselves naturally, the voids around the half spheres adjacent to the wall would be 65 per cent of their volume while those around the other half (away from the wall) would be 35 per cent.

This shows quantitatively the effect of the wall in

increasing the interstics under conditions in which we can calculate it, and the general nature of the effect is the same in irregular materials.

It is an old tradition in the business that the fine material must be put against the walls and it is obvious from these considerations that this is correct, and therefore the fines, that is the ore in modern practice, must go largely against the wall if we are to avoid excessive flow of gas there. Therefore we need now a single bell of rather large diameter in proportion to the stock line, but in the days of lump ores it was possible to carry this to an extreme and to have the charge column too open through the center and an excess flow of gas there, so it was desirable under those conditions to dump part of the charge in the center so that some fines would reach that part and help to obstruct it.

Mechanical Charging

Many attempts had been made to use the skip for filling purposes as well as many other mechanical appliances which would at least permit the elimination of the top fillers, usually the hardest worked, and always the ones with the greatest capacity of doing harm by improper dumping. But the results of all these early attempts had been excessively unsatisfactory because the work of the furnace was so much poorer that increased fuel consumption, diminished output, lowered quality of product, and reduced life of lining amounted

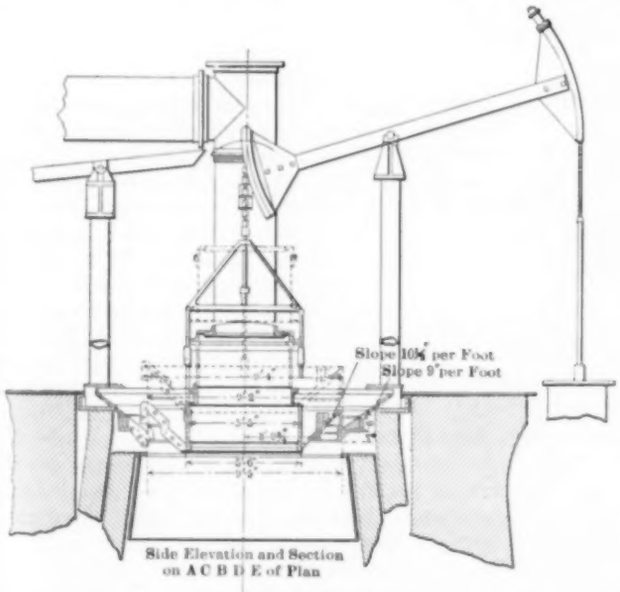


FIG. 10—DOUBLE LANGEN CHARGER DESIGNED BY FRANK FIRMSTONE FOR THE GLENDEN IRON WORKS

to very many times more on the debit side of the ledger than the slight saving of labor on the credit side.

In that early day it is well to note that the barrows were generally filled by hand shoveling, furnace operators having been exceedingly slow in realizing the value of bins. The idea that the greater portion of the work of the bottom fillers could not be reduced explains why the early attempts at mechanical filling were directed mainly at eliminating the top fillers. This made the saving relatively small, while the loss due to bad distribution may easily be, in fact generally is, of enormous proportions, and may quickly convert a profitable into a bankrupt concern.

With the rapid increase in output which took place in the early nineties and culminated in the Duquesne revolution, the difficulties of filling the furnace became more and more serious. In addition to the vast difficulty of training and keeping crews of the size necessary to do this work by hand, and of supervising their performance of it to secure good furnace operation, it became almost a physical impossibility to handle the number of barrows required, and get them on and off of the hoist platform at the top and bottom of its travel, even though the operation was kept up at the highest possible pressure for twenty-four hours a day and practically without intermission. If any interruption occurred it became more and more difficult to "catch" the furnace after the stock line had gone down below the proper level; the fillers were kept almost up to their maximum speed to keep even with it under normal conditions and obviously had to make a stern chase in order to overcome any lead that it might get by an interruption in the charging.

The great expense of this method also became more and more obvious as the number of men required increased, and looking at the matter from the financial point of view it was well worth while to make an investment which would eliminate the labor of sixty men, while the same investment to eliminate the labor of only twenty might be a very poor one. In other words the annual cost was high enough to pay fixed charges on a heavy plant investment if a suitable means could be found for filling the furnace mechanically.

The necessities of the case were so great that renewed and more extensive efforts were made to solve the problem of stock distribution mechanically, and in the middle nineties a number of designs were brought out by various engineers for the accomplishment of this purpose.

For a long time after the introduction of the bell and hopper to close the top of the furnace no effort was made to prevent the escape of the gas during the time that the bell was open for the introduction of the stock, but with the increased appreciation of the value of this excellent fuel it became more desirable to prevent even this waste, amounting to some 3 to 10 per cent of the total gas produced, and for this purpose a secondary valve or seal was sometimes provided which was closed before the main bell was opened, and opened only after the main bell was closed.

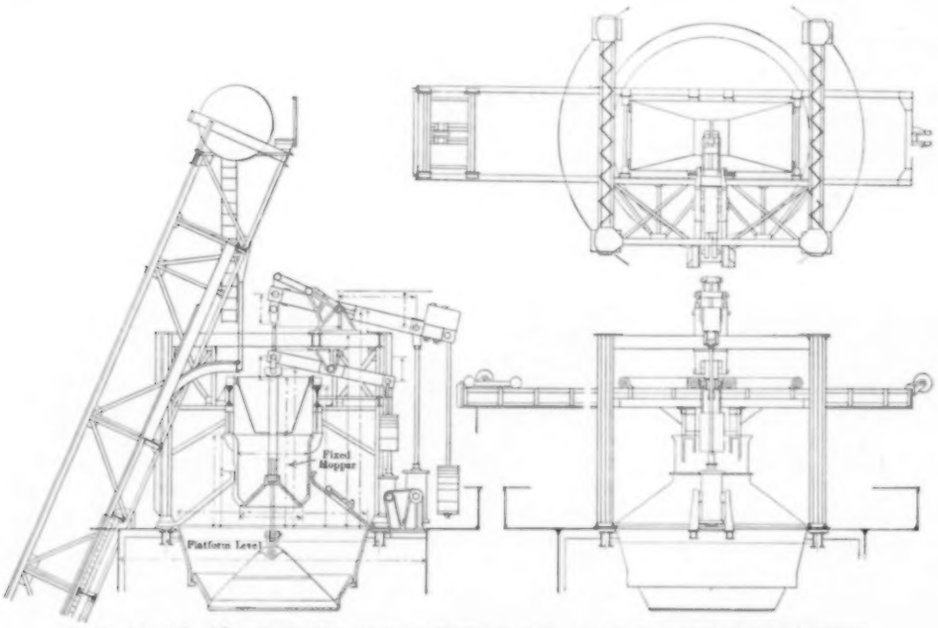
One of the earliest forms of this apparatus consisted of a huge iron lid like a pot lid, which was lowered down onto the top of the hopper before the bell was opened, and raised again after the bell was closed.

The introduction of mechanical filling made the closing of the furnace top while dumping the main bell easier and more desirable, and the obvious method of doing this was by the use of an apparatus similar to the air lock used in caisson work which in this case becomes a gas lock in which one valve opens from the outside into the lock, the other opens from the lock into the furnace. The bell having so firmly established itself as the only valve worthy of consideration for closing the furnace top it was perfectly natural that a similar bell should be used for the top valve of the gas lock, and this has become almost universal practice. This was the plan adopted at the Edgar Thompson Works, and in several with other designs.

The development of the double bell type of furnace top made the closed position of the gas seal bell the normal one, and this is greatly to be preferred because with mechanical filling it is possible to operate for a considerable period with the main bell leaking quite freely, if the gas seal be reasonable tight, and if its normal position is closed. But if its normal position be open the leaking gas meeting the air burns up through the throat of the furnace and is likely to do great damage to all the mechanism, even to the extent of softening the rod of the main bell to the point where it can no longer sustain the weight of the latter, and thus causing its loss into the furnace, an accident involving a

frightful amount of hard work and serious financial loss due to a shut down of from twelve to forty-eight hours, according to the style of top and the preparedness of the management for such emergencies.

With the gas seal bell normally closed it cuts off by far the greater portion of the leakage of gas and reduces it to an amount whose combustion can do but little harm. I have run a furnace for several days with a huge piece out of the main bell, because the hood and the gas seal being tight the quantity of gas which could escape was unimportant, but it would be impossible to operate a furnace in this condition if the normal position of the gas seal were open, because such a quantity of gas burning continually would destroy the furnace top completely. Even a much smaller leak is a very serious matter under these conditions; the result is that more work is required to keep the furnace top tight enough for safety, and main bells have to be changed more frequently because only small leaks past them can be tolerated.



FIGS. 11, 12, 13—ROBERTS NON-ROTATING TOP WITH ADJUSTABLE HOPPERS

There are two broad classes of mechanical filling as already described in the second article of this series, which may be broadly called "bucket filling" and "skip filling." There are several varieties of each, though the variations are much more matters of detail than of principle. It will be easier to discuss the points of the bucket system after considering the different types of skip filling, and we will therefore consider the latter first.

The first installation of skip filling commercially successful on a large scale was made at the Edgar Thompson Steel Works, under the supervision of their furnace superintendent, G. C. Kerr (now first vice-president, United States Steel Corporation) and chief engineer, E. E. Slick (now vice-president and general manager, Cambria Steel Company). By careful, painstaking and long-continued experimentation with model tops built exactly to scale, and raw materials crushed and sieved to the same scale, the proportions were found which would give a reasonably uniform and satisfactory distribution of the stock on the bell. A furnace was equipped with a filling apparatus of this design, and it was so successful that except for minor details nothing else has ever since been used at that plant, a record which I think is better than that of almost any other plant in the country since many of them have tried out two or three, and others very many more types of tops.

A typical double-bell furnace top is shown by Figs. 11, 12, and 13, in which the main bell and hopper, the upper or gas seal bell with the hood to connect the seat of the upper bell with the top of the hopper, and all the accessories of the top, including the skip, are well shown.

The upper bell does not need to be nearly so large as the lower one since the diameter of the latter is controlled by the size of the furnace top into which it discharges the charge, but the charge will arrange itself on the main bell in very much the same way irrespective of the size of the upper bell. In fact the small size is of decided advantage, since the nearer the stock enters through a mathematical point in the center of the furnace, the more uniform will its distribution be. If the upper hopper be large, and the stock be delivered into it irregularly by the skips, a greater or less portion of these irregularities will follow through the upper bell down into the lower. The larger the hopper the greater these irregularities may be, and the more completely they follow down onto the main bell, and so into the furnace.

Many plants have adopted what is known as the plain double-bell style of skip filling, but many have had most disastrous results with it, and others after the most careful and conscientious trials to obtain an exact distribution, have reached the conclusion that no form or design of this top is satisfactory because the distance which the materials travel is effected by the size, shape and moisture contents of the different materials and by the velocity of the skip when dumping. What is a perfect distribution on a dry day may be a frightfully bad one during a rain storm if the ore becomes wet, while a good distribution for a coarse coke, free from fine material, may give horrible results with a fine coke much broken up.

Various ingenious schemes have been used to eliminate or control these irregularities, and baffle plates without number have been tried and then discarded for the reason that no matter how good the results might be with one condition, they would infallibly be bad with some change in the conditions, such as was sure to arise within a short time, in ordinary operation. Two of these attempts may be mentioned as showing the lines of endeavor.

The Roberts top designed by Frank C. Roberts of Philadelphia is shown by Figs. 11, 12, 13, showing a central section in the plane of the skip, a front elevation at right angles therewith, and the plan view showing the receiving hopper divided into two triangular pieces, more properly half pyramids, the hopper being a truncated pyramid with its axis in the center line of the furnace, and cut in two in the central plane between the skips. Each of these half hoppers is mounted on four wheels resting on a stationary track at right angles to the plane of the skip. The treads of the wheels are wide, and their flanges set back well inside the line of the track so that the half-hoppers cannot only be moved in and out, but can also be slewed in the horizontal

plane in order to secure that distribution which, under test, seems to give the best results. In other respects the design is similar to that of any other double bell type of top.

The Rowe Top was invented by a young man of that name at a plant where they had suffered greatly from bad distribution. The extreme simplicity of his design enabled it to be applied to the furnace with only a short shut-down, and this application resulted in an immediate and decided improvement in the practice. Unfortunately no drawing of this top is available, but it may be described without much difficulty.

A vertical plate was set up in the hopper immediately under the dumping position of each skip and in its central plane; this served to divide the skip load into two precisely equal halves. To this vertical plate were fastened inclined plates which ran down into the throat of the hopper, one of them sloping from the top corner next the skipway to the opposite bottom corner, and its companion plate on the other side sloping from the top corner farthest from the skipway to the diagonally opposite corner of the vertical plates, so that the planes of the two plates made a letter X, but one line of the X was on one side of the vertical center plate, the other on the opposite side. The bottom ends of the inclined plates were located approximately at the quarter points around the circumference of the throat leading to the bell. Consequently as each skip load came up it was divided into two halves, and those two halves placed on two adjacent quarter points around the throat, similarly when the other skip came up its load was halved and delivered to the other two quarter points.

It is obvious that this action would be but little affected by a change in the velocity of the skip in approaching its dumping position, or by changes in the size, stickiness, etc., of the materials, or at least the changes so produced would be very much smaller than they would if the skips dumped directly and delivered all their material on one side or the other of the throat in accordance with variations in the conditions.

One of the earliest designs was that of M. A. Neeland, at the Ohio works of the National Steel Company, where the throat of the furnace was made quite high, and had set inside of it sloping vanes, roughly like a screw thread, which caused the material to whirl around as it descended through the throat, and as a result of this whirling it was hoped to get a uniform distribution of the stock.

Very much may be done to secure regularity by correct proportioning of the main parts of the apparatus, the location of the skips in their dumping position, the size and shape of the receiving hopper which delivers the material from both skips alike to the throat, and many other details. Each has its effect on the general result, and while many devices such as those mentioned are available, it is far better not to trust to any of these alone but to eliminate the principal irregularities as far as possible by correct design in the first place, even then there will be plenty for the secondary devices to do to secure good distribution.

These irregularities were in several cases within my own knowledge very great. It did not require accurate measurement of the heaps and gaging of the size of the materials in each portion to show this; it was obvious to the most casual observer. The really remarkable feature of the whole situation was that many furnacemen did not recognize the source of their trouble or in some cases did recognize it, but were not allowed to correct it, because to do so would reflect on a design which had been selected by their superior officer.

At one plant using lump ore which I visited about ten years ago I was taken up to the top of the furnace by the stock house foreman. Of the skip load which lay on the upper bell about two-thirds lay on the side next the skipway and consisted of all the finest portion of the load, while the one-third on the opposite side contained all the coarse! The stock house foreman said he thought that gave a very good distribution and when I asked him where the "hot spot" was of which he had told me he pointed down directly in the line of descent of the coarse material.

"Breakage of the Coke"

One of the most important factors in the whole subject of furnace operation was overlooked in the early designs of mechanically filled furnaces. This was the question of breakage of the coke. In some plants this seemed to have been almost totally disregarded. Coke was dumped from hopper cars on high trestles into bins perhaps almost empty, involving a drop of 15 to 25 ft., dropped again from the gate of the bins to the bottom of the scale car or bucket, 6, 8 or 10 ft. more, dropped from the scale car into the skip, a distance equal to the last, from the skip into the receiving hopper some 7 or 8 ft., from the upper bell onto the main bell, about an equal distance again, finally from the main bell onto the stock line, some 8 or 10 ft., if the furnace were full, up to any distance if it were empty.

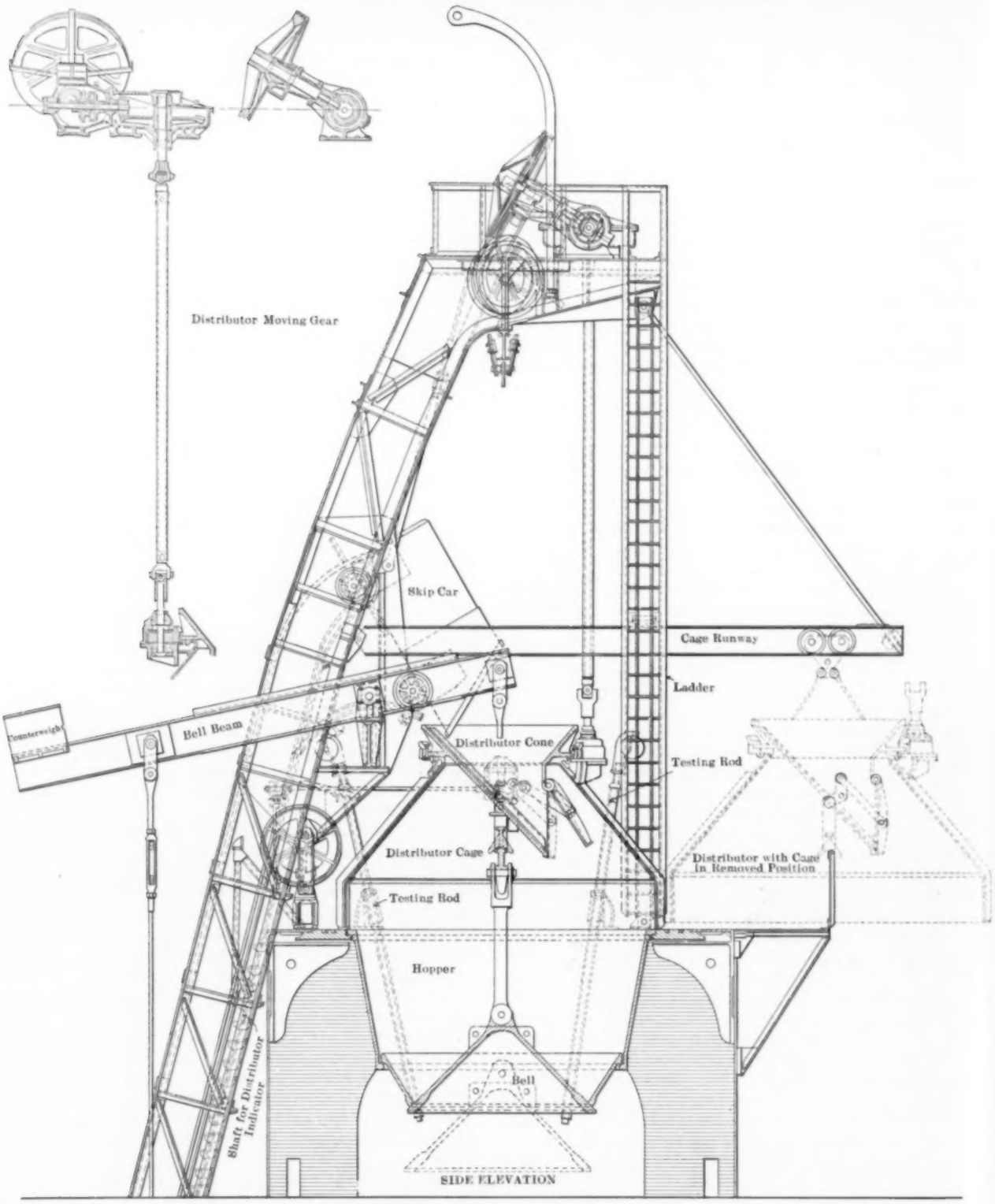
The detrimental action of fine coke in the furnace, and its much reduced fuel value, particularly for heat in the hearth, are well known, and need not be further stressed here though apparently they were overlooked by some of the furnace designers of fifteen years ago. Just how much the coke was broken up, and how much the average size of the individual pieces was reduced, what percentage of detrimental fines were made by this treatment in extreme cases, we shall never know now, perhaps it is just as well that we should not. But the general result was seen in the fuel consumption, and eventually in the cost sheet of many of these plants, while the furnace manager, who in most cases was not responsible for the design, spent many unhappy hours over these conditions for which he had in many cases to take the blame.

It will be noted that with the Duquesne system, presently to be described, the buckets were so designed as to come close up under the bins with only a short spout beneath the gates of the latter. This reduced the drop into the bucket to the minimum, and eliminated two dumpings of the coke as compared with those plants where it was transferred first to the scale car, and then to the skip before reaching the upper bell.

It is altogether possible that this feature had an appreciable influence in bringing about the early success of Duquesne as compared with many of the skip-filled furnaces built soon afterward. Now furnace managers and engineers understand this matter of coke breakage better, and it is recognized that no top should be permitted to give the coke an inch more drop than is absolutely necessary to accomplish the transfer of the stock.

In more recent years the "shatter test" of coke has been invented and attention is paid to the strength of the coke, so that more is known as to the injury done it by any given drop, but with this advance has gone the increasing realization that every unnecessary foot of drop was highly objectionable and could not fail to cause some proportionate share of increased coke breakage.

As a consequence the enormously long throats which were used on some furnaces fifteen years ago have disappeared and one of the major considerations of the present day in regard to any system of filling is its probable effect on the coke. Considering all these important points which were largely or wholly ignored or neglected the only wonder is not that furnaces did bad



FIGS. 14 AND 15—BROWN ROTATING TOP

work in the early day of mechanical filling but that they ran at all.

Rotating Tops

If the location of a given irregularity be rotated through an angle increased by a definite amount at each charge, we shall obviously obtain the equivalent of spiral hand filling and so by evening up over a number of charges the kind of material delivered to each portion of the furnace circumference shall secure the equivalent of uniform filling in each charge. Furnace tops which operate on this principle are called rotating or revolving tops.

There are in use three principal types of rotating tops—the Brown, the Baker and the McKee. All of these are patented and the whole subject has been one of much complexity, not only technical, but to some extent legal. The merits and demerits of the different types of apparatus have been the subject of acute and heated discussion. Each of them has been thrown out of use at one or more plants, and it is therefore necessary to admit that there are objections to all of them.

To state these objections as well as their advantages fearlessly and firmly is the only course open for a satisfactory treatment of this subject; however far short of this object I may come, this at least will be my aim.

The Brown Top

Although I have referred to the persistence of hand-filling as almost universal up to the time of the Duquesne revolution it is a fact that the first reasonably satisfactory apparatus for mechanical charging had been introduced several years before. The skip which dumps by turning nearly upside down, as described in the second article of this series, has been known for a long time. I am told that it was used two hundred years ago in Sweden. An attempt was made to use skip filling by Fayette Brown, the father of the late Alexander E. Brown. It is said that the furnace so filled worked irregularly in the way in which so many such furnaces have done, and the skip was therefore thrown out. In order to secure symmetrical distribution with hand filling it occurred to Fayette Brown to put a cover over the entire hopper with a single opening through it large enough to admit of dumping only one barrow, and at a certain definite location. This cover was revolved about the axis of the furnace by a mechanism driven from the hoist sheaves, so that this opening advanced one dumping space at each revolution. This, of course, forced the top fillers to dump correctly.



FIG. 16—BROWN TOP REMOVED FROM FURNACE



FIG. 17—RROWN TOP ON FURNACE

Many years later it occurred to Alexander E. Brown to combine this controlled system of dumping with the skip hoist by having the skip deliver into a central hopper with an outlet spout on one side, and revolving this hopper and spout around the vertical axis of the furnace by a mechanism driven from the hoisting sheaves, and this is the essential principle of the "Brown top," at least one of which was in operation several years before the Duquesne revolution, and has, I think, continued in operation from that time to this.

This top as now built is shown by the line drawings, Figs. 14 and 15, and by the photographs, Figs. 16 and 17. At the bottom of the line drawing are shown the bell and hopper; above these, on the top of the furnace proper, is the conical gas seal which acts as a support for the revolving distributor and the gears which drive it. Above the hopper is seen the skip in its dumped position, and at the top the main rope sheave, with the gears through which it drives the vertical shaft descending to the gear box just outside the distributor cone, through which the latter is revolved. The detail of the sheave and the upper gears is shown in Fig. 15.

The gas seal consists of a flap valve on the spout of the receiving hopper whose normal position is open, as shown in full lines in Fig. 14, but which is closed by the first portion of the movement of the main bell, acting through the bell crank shown in dotted lines. This gas seal is not as tight as a bell and is subject to the objection above described, that its normal position is open, so that if the main bell is leaking to a considerable extent the gas can rise through the spout and burn almost without interruption around the upper portion of the top mechanism.

There is a ratchet in the mechanism which drives the hopper when the sheave runs in one direction, but allows it to stand still when the sheave runs in the opposite direction, on the return trip; thus the hopper is rotated a definite amount with each trip of the skip.

At this point Mr. Brown introduced an admirable feature into the design. Instead of having the distributor rotate through an angle commendable with 360 degrees, so that it would always return to the same position at the end of every complete revolution, he designed it to revolve two or three degrees more or less than a quarter of a revolution, so that at the end of four movements it is some ten degrees one side or the other of the point at which it started, and only after many revolutions, representing a great number of charges, does it return to its initial point. This has the great advantage of giving not only each segment, but each fraction of the circumference of the furnace exactly the same treatment, and this is greatly to be preferred to any system which must always use the same starting point,

since in that case any irregularity due to the difference in shape of the first skip load dumped and the last, or the like, is localized in one place and may cause serious trouble, whereas if it went to each point of the circumference in turn it would do no harm.

Any mechanism at the top of the blast furnace has to operate under extremely difficult conditions. It is necessarily surrounded by the dust arising from the different components of the charge which is sharp, gritty, and destructive to the last degree, and is exposed to temperatures not infrequently above any at which lubrication is possible, and if there be a leak of the main bell so that gas escapes at all freely, the apparatus is entirely likely to be subjected to direct flame. These

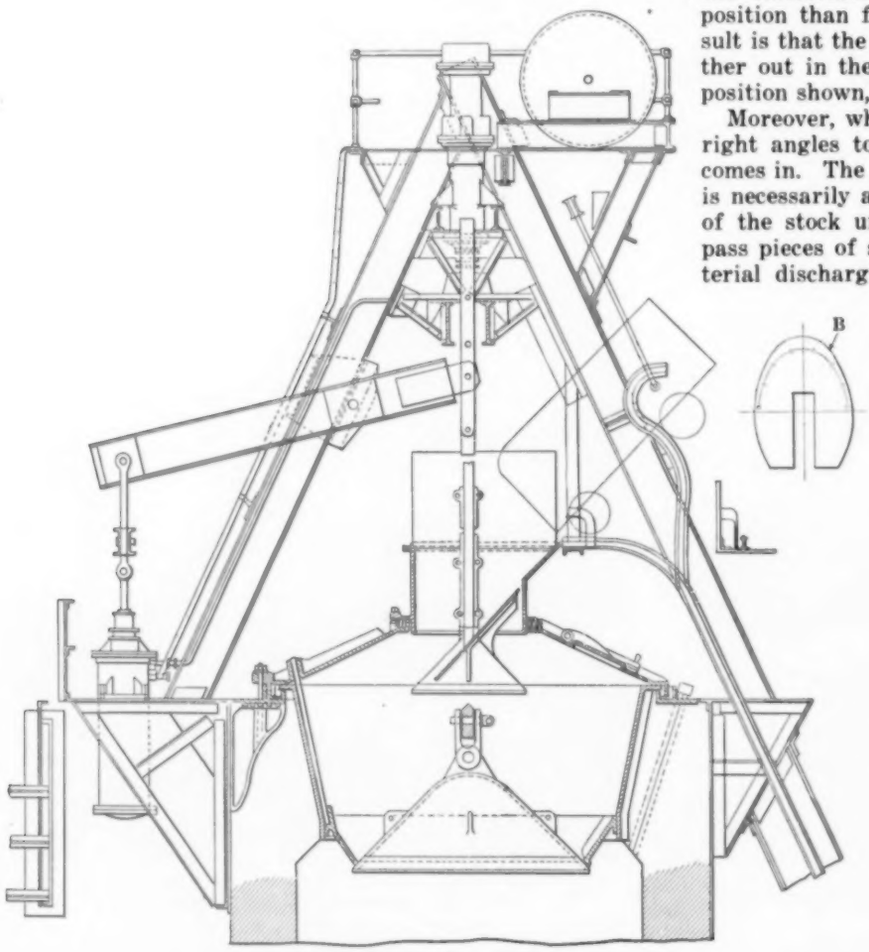


FIG. 18—BAKER ROTATING TOP

conditions are so severe that they alone have caused the defeat of many tops, and in the early days they undoubtedly caused many mechanical difficulties in the operation of the Brown top.

With the passage of time many of the features of the design which caused these difficulties have been overcome, and in the North where furnace tops commonly work at quite low temperatures, about 400 deg. or below, these mechanical troubles have not been so severe, but in Southern practice, with greater coke consumption, and much hotter top conditions, the Brown top has in more than one instance been discarded for the purely mechanical reason that it could not be kept in successful operation, the situation frequently being complicated by the fact that mechanics of sufficient skill to operate a mechanism of this kind successfully were, in past years, scarcer in the South than in the North.

In addition to these mechanical difficulties of operation the Brown top in spite of its appearance of perfect symmetry does not give an absolutely symmetrical distribution.

An examination of Fig. 4 will show that the line of the distributor in the position drawn is practically a continuation of the line of the bottom of the skip, so that the material discharging from the latter has only to continue on its way straight through the distributor, and is thereby delivered from it with velocity practically unchecked. But when the discharge spout of the distributor is in the position opposite to that shown, its slope is almost at right angles to the line of discharge from the skip, and material delivered upon it is therefore brought practically to a standstill, and starts again virtually from rest, so that its velocity of delivery from the distributor is very materially less from this position than from the position opposite. The result is that the material is thrown considerably further out in the hopper with the distributor in the position shown, than in its opposite position.

Moreover, when the spout of the distributor is at right angles to the position shown, another effect comes in. The spout is not a mathematical line, but is necessarily a broad opening to permit the escape of the stock under any and all conditions, and to pass pieces of scrap of considerable size. The material discharging into the hopper from the skip has a very considerable horizontal component to its velocity when it strikes the distributor, and instead of discharging down the axis of the spout, this horizontal velocity takes it over to the far side of the spout, whether the latter be turned toward or away from the observer.

The effect of this is, of course, to put more material on the side of the bell opposite to the skip than on the side next to it. In other words, in spite of the axial location of the center of the distributor the horizontal velocity of the stock imparted by the skip persists to some extent and carries the center of gravity of the pile of stock as it rests on the bell considerably beyond the axis of the furnace. That is the side of the furnace next the skip receives a considerably smaller portion of every charge than does the opposite side. Unsatisfactory furnace work has been traced directly to this cause in several cases.

The Baker Top

This may be considered as a modification of the Brown top in that it distributes the material in heaps on the main bell. It is shown by Fig. 18. Endeavor has been made in the design of this top to overcome the mechanical difficulties due to the great weight of the rotating parts, the large radius of the sliding surfaces in the Brown and the somewhat complicated mechanism required to drive it, and also to reduce to a minimum the height from which the coke is dropped so as to reduce coke breakage. The main bell, hopper, and lip ring are clearly shown by the drawing, and are of standard construction, but, as is necessary in most central types of stock distribution, the main bell is not supported on a single central rod; instead it is hung to a horizontal central equalizing beam from the two ends of which rods run up to the ends of the double main bell beam. A section of the equalizing beam, with its sharp-edged top

to divide the current of stock, and prevent any disturbing action on the descent of the latter, is plainly shown on the drawing. The main bell rod on the far side is shown broken away below the top of the upper hopper, but a short piece is shown attached to the end of the main bell beam.

In this design there is a gas seal bell practically identical with the upper bell of the ordinary non-rotating double bell charging apparatus, but in this case the bell has fastened to it a plate which is elliptical in outline and is set parallel to one side of the conical surface, and constitutes a sort of slanting piston working in the receiving hopper which is nearly cylindrical, diverging slightly at the top, as shown in the drawing. The upper bell is rigidly keyed to the lower end of its central bell rod. By means of its suspension rod the bell with its extension plate attached is rotated through a certain angle each time it is raised and lowered. When the upper bell is open, and in the position shown, the plate acts practically as a continuation of the lip of the receiving hopper and discharges the entire skip load on the opposite side of the furnace. The upper bell is then closed and opened again, which brings the deflecting plate into a position in the horizontal plane approximately to right angles of that shown. This delivers the next skip load onto the bell practically at right angles to the first one, the third is approximately opposite to the first, and the fourth practically completes the cycle, but if the "hunting tooth" effect used by Brown is desired, the cycle is not exactly completed.

Instead of an arrangement of gears for rotation recourse is had to what is known as the rifle barrel cylinder. This device has been in use for many years for securing the rotation of rock drill bits. The cylinder which operates the upper bell is immediately over it, and inverted so that it operates directly without the intervention of levers or other devices. This makes an extremely simple design.

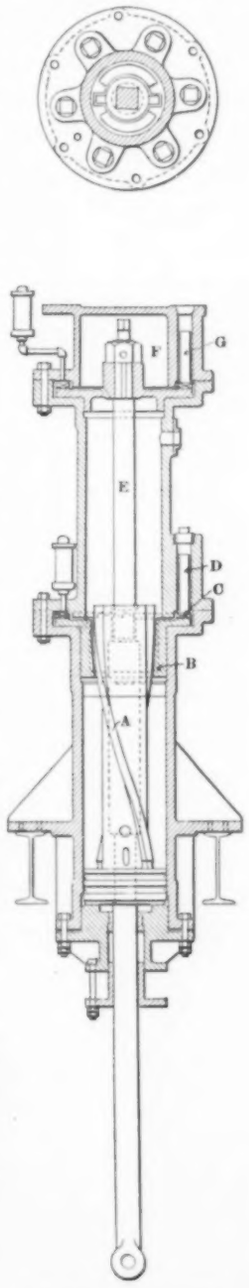
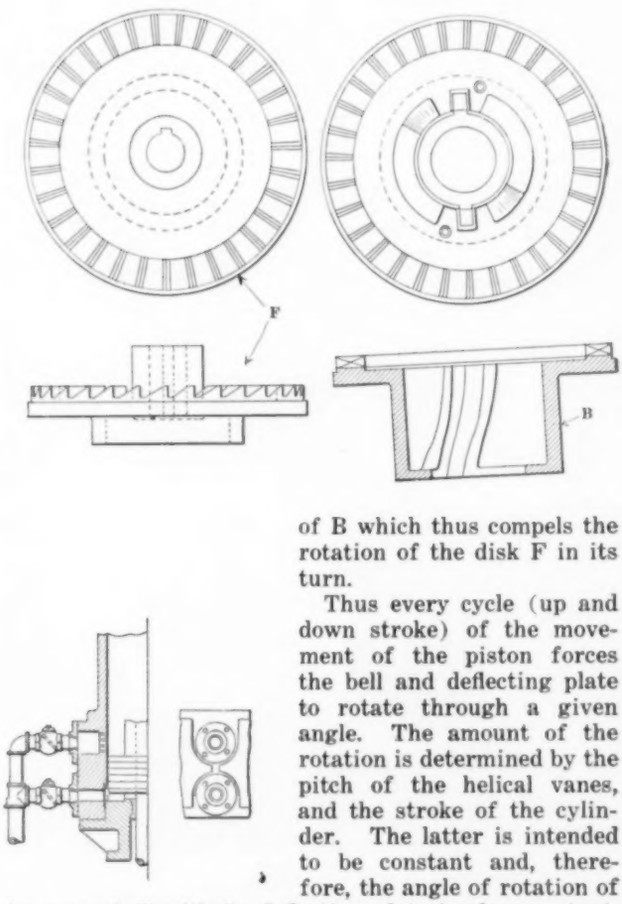


FIG. 19—ROTATING GEAR OF BAKER TOP

The operation of the rifle bar cylinder is shown by Fig. 19. The piston carries two helical vanes A which work in corresponding grooves or threads in the nut B which has ratchet teeth cut in its upper surface. These are engaged by vertical gravity pawls D in pockets spaced around the cylinder. They prevent the rotation in one direction of the nut B. A square opening at the top of the chamber on which the helical vanes are cast is an easy sliding fit on the square rod E, which carries on its top a circular plate F, to which it is rigidly keyed, and which has on its top surface ratchet teeth engaging with pawls G exactly the same as those of B and operating in the same direction.

On the down stroke of the piston, the action of the vanes forces either F to turn to the right or B to the left, but the ratchets G do not allow F to turn to right while the ratchets D do allow B to turn to the left, which it does. On the up stroke the pawls engage with the ratchet teeth C and prevent the backward rotation



of B which thus compels the rotation of the disk F in its turn.

Thus every cycle (up and down stroke) of the movement of the piston forces the bell and deflecting plate to rotate through a given angle. The amount of the rotation is determined by the pitch of the helical vanes, and the stroke of the cylinder. The latter is intended to be constant and, therefore, the angle of rotation of the upper bell with its deflecting plate is also constant.

The upper portion of this cylinder has no function except to enclose the apparatus and prevent the entrance of the grit and dirt which always abound on top of furnaces, and which have done so much to destroy charging mechanism. The cylinder is virtually a single-acting one, since the weight of all the parts acts downward and suffices for the down stroke, steam being used only for the up stroke and to cushion the down stroke.

This type of top has given good satisfaction at a number of plants, but its use has been abandoned at a number of others, since it was claimed that the benefit obtained from its form of distribution was not sufficient to offset the possibility of the small bell being stuck with its deflecting plate in one position, and dumping the stock to one point on the main bell for a number of charges, or even hours, if this condition was not discovered. For it is evident that if the small bell fails to operate between skip loads the position of the deflecting plate will be left unchanged, while there is nothing to prevent the indefinite continuance of dumping in this position. This, of course, would make the worst possible type of stock distribution, and would ruin the work of any furnace in a very few hours.

There is with this design the possibility of jamming

the deflecting plate against the wall of its slightly tapering receiving hopper by the entrance of lump material back of the plate, and while the probability seems slight, this chance, in addition to the discarding of the top by at least one large plant has proven sufficient to reduce its popularity. It is probable that the top has been successful at plants using lump ore, or a mixture of lump and fine, and less successful at plants using all fine ore, for reasons which will appear later. This is in accordance with the facts in regard to the continued use of these tops. Those within my knowledge at plants where the ore mixture is lumpy have given far greater satisfaction than those in the Lake Ore district.

The McKee Top

It has been very widely believed by many furnace men, and is even yet, that one of the essential characteristics of a revolving top is that if the revolving apparatus ceases to work it should still continue to give



FIG. 20—KENNEDY TOP

a reasonably good stock distribution. This means that dumping in heaps is barred because as explained in regard to the Brown and Baker tops, if they cease to rotate they give the worst conceivable distribution. This then implies that the stock must be dumped in annular layers as nearly uniform as possible, and that any irregularities in the layers due to the irregular discharge by the skips into the receiving hopper must be eliminated by revolving the latter.

This idea seemed to have occurred almost simultaneously to various engineers, but the credit for having first applied it successfully undoubtedly belongs to Arthur G. McKee of Cleveland.

The earliest form of this top consisted simply of a conical receiving hopper into which the skips dumped, terminating in a hopper of steeper slope below whose bottom was closed by an ordinary gas seal bell operated through a hollow bell rod which encircled the main bell rod. The hopper was mounted on ball bearings set well back from the line of the hopper, and carefully designed to keep the dust out from above, and give it ample opportunity to fall out below, holes being drilled at intervals in the bottom of the ball race to facilitate the latter purpose.

The gas seal bell, of course, requires to rotate with the hopper and therefore the hollow bell rod is provided with a small ball bearing near its upper end to permit the lower part and the small bell to rotate without interfering with the operating mechanism above.

Probably one of the most important features of the design practically is the extension of the ball track to a path well outside of the closest point on the hopper, which is carried by radial arms extending in from the upper ball race. This makes an air space between the ball race and the hopper so that unless the latter be heated to a red heat or above, the ball race still remains relatively unaffected and able to perform its functions.

This apparatus is not driven by the rotation of the sheaves through ratchet wheel and gears as in the Brown, but is provided with an independent motor operating through reduction gearing and controlled from the operating platform at the bottom of the furnace.

The general appearance of this early form of this top is shown by Fig. 20, which however is not a McKee top, but a top designed by Julian Kennedy of Pittsburg, on exactly the same principle as the McKee, but rotated by a wire rope passing around the hopper and down to the ground level, where it is moved by hydraulic cylinders or other suitable mechanism to give the desired rotation to the hopper. In principle the design is in all respects similar to the McKee.

In the McKee top contacts are attached to the hopper at four points and by means of wires carried down to the operator's platform these light indicator lamps when they come into certain positions.

In operating this first design a skip was dumped into the hopper which was then rotated through ninety degrees. The second skip was then dumped and the hopper again rotated, and so on to the fourth skip load which completed the cycle, the upper bell was then opened, permitting the charge to descend onto the main bell from which it was dumped after the upper bell was closed. The process was then repeated.

Almost innumerable modifications of this system were designed to eliminate certain irregularities which briefly are the same as those I have pointed out in connection with the dumping of barrows into the hopper in hand-filling. The location of the first skip load in the hopper and the room it occupies is very different from that of the second and third, and still more different from that of the fourth, which is likewise different from that of the second and third. Moreover with the double skip there was a serious irregularity which does not appear from the examination of a side elevation of one of these tops. From this it might appear that both skips dumped in the central plane between them, but as a matter of fact one dumps well on one side, and the other as far on the other side of this central plane, so that two successive loads are a considerable distance apart in the hopper irrespective of its rotation. It will be obvious on a little consideration that when this distance is combined with that arising from the constant angle of rotation, two adjacent skip loads may be the sum of these two distances apart, and the next two only their difference, with consequent great variation in the shape and location of the resulting heaps.

Many furnaces equipped with tops of this type while they apparently had a good stock distribution, gave extremely poor results, and as furnaces working under very different conditions showed similar results along a certain line which was not nearly so noticeable with any other type of top, it seemed reasonable to assume that the trouble was due to this type of distribution.

The furnaces filled in this way scoured out their linings in a zone twenty or thirty feet above the tuyeres, not on one side as so frequently happened with non-rotating skip-filled furnaces, but quite regularly all

around. The blast pressures were high, furnace control unsatisfactory, and fuel consumption apt to be excessive.

The real reason for these results has, so far as I know, never been worked out, but that they did exist, and that they were directly chargeable to the type of distribution used at least in one case has been demonstrated in my own experience so clearly that no unprejudiced observer could retain any possible doubt. I shall revert to this phase of the subject later.

It was in order to overcome these difficulties, whatever their reason may be, that Mr. McKee has in recent years redesigned his top so as to eliminate some of the worst irregularities. The new design is shown diagrammetically by Fig. 21.

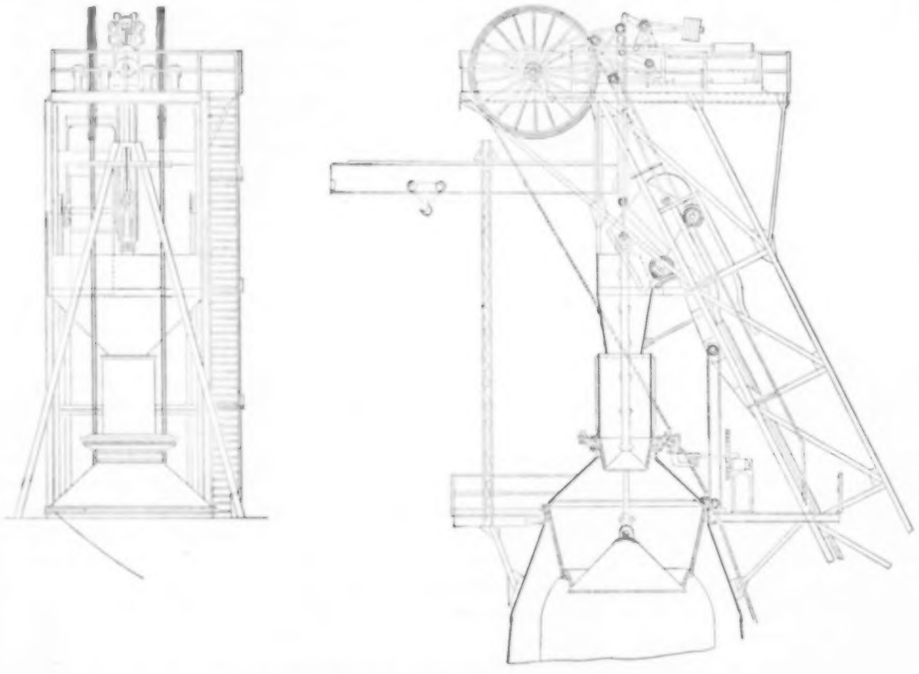


FIG. 21—RECENT DESIGN OF MC KEE TOP

The original rotating conical receiving hopper is entirely eliminated and is replaced by a flat triangular stationary receiving hopper through which each skip load in turn passes into the cylindrical rotating hopper below. This has the great advantage of practically centering the charge to begin with, and thereby eliminates some of the worst irregularities of the original design.

The revolving hopper is now being rotated preferably to six points instead of four, and so equalizes any irregularity which may occur in the discharge of the skip load into the hopper by throwing it to each one of the six successive radial positions in turn.

The design of ball races carried well away from the hopper proper, the provisions for preventing the entrance of dust and for allowing it free exit are maintained substantially as they were in the earlier design. It is no more than fair to say in this connection that mechanically this top in my experience gave a minimum of trouble, and I think that this experience has been quite general. I have not operated any furnaces with the improved design, but my information is that many of the troubles which prevailed with the older design have been diminished with this, and that the results are very much better, as is to be expected from the removal of the irregularities due to the varying distribution of the skip loads around the conical hopper.

(*To be concluded in April issue*)

The Hardening of Metals before the Faraday Society

The last meeting of the Faraday Society in London was devoted to an interesting symposium on the hardening of metals.

The president, Sir ROBERT HADFIELD, opened the discussion with an introductory address. Referring to the history of the most important "hardened" metal in the world, namely steel, he said that the world's future progress literally depended upon understanding correctly and in a scientific manner "the hardening of metals." The accurate determination of the hardness of steel alloys was now being investigated by a special research committee of the Institution of Mechanical Engineers. They were that night going to discuss the *rationale* rather than the practical applications of hardening. Having referred with deep regret to the great loss sustained by the science of metallurgy in the death of Dr. Martens, in whose honor Osmond had invented the metallographic term "martensite," he concluded by showing a specimen, probably the first to be exhibited in modern times, of an ancient piece of high-carbon steel which had been hardened by quenching. It was taken from beneath the stone pillar of Heliodorus at Besnagar, India, and it contained 99.2 per cent. Fe, 0.70 per cent. C, 0.04 per cent. Si, 0.008 per cent. S, 0.20 per cent. P, 0.02 per cent. Mn, and traces of nickel and chromium. This specimen, perhaps more than two thousand years old, was the first example of ancient steel which he knew of that contained sufficient carbon to be called steel.

Dr. G. T. BEILBY read a paper entitled "Some Recent Papers on Hardening and Overstrain in Metals, and the Bearing of These on the Author's Amorphous Theory of the Hardened State."

I. Hardening of a pure metal may be caused by cold working or by chilling.

II. Hardening of alloys, of mixtures of metals, or of mixtures of metals and metalloids may be caused by cold working, by chilling, or by the mere admixture of different kinds of molecules, either simple or compound.

In Class I, if the amorphous-crystalline theory of the hard and soft states is accepted no further explanation is needed, but in view of the fact that this explanation is not yet universally accepted, the facts and conclusions on which the theory is based are briefly discussed. The essential distinction between molecular aggregation in the two states is shown to consist in *mutual constraint in the one state and freedom of vibration in the other.* The vibrational freedom of the molecules in the crystalline state is an essential and characteristic feature of that state and inevitably leads to potential mechanical instability. Mutual constraint of the molecules in the amorphous state inevitably leads to greater mechanical stability. Mutual encroachment into each other's sphere of vibration enhances the mutual attrac-

tion of the encroaching molecules. This view falls in line with the ascertained facts as to the storage of energy in the hardened metal which is released on solution, the loss of elasticity evidenced by acoustical and other phenomena, and the electrical, magnetic and optical phenomena which probably indicate interference with the freedom of the electrons as well as with the vibrational freedom of the molecule as a whole. Further the mechanical instability of the crystalline state is shown by the ease with which the surface of even brittle, non-plastic, crystalline metals and other substances can be flowed into a smooth, hard, vitreous layer or skin. The steps in the recrystallization of the hardened metal as the temperature is raised to the point at which the whole mass is apportioned among fully developed crystalline grains supply further confirmation of the reality of the distinction between the two states.

Class II. The hardening of alloys and mixtures. If the amorphous-crystalline theory is accepted for Class I it must also be accepted for Class II, wherever the condition of flow at internal surfaces can be shown to exist either as a result of cold working or from contraction strains due to chilling. In this class the amorphous or thermally metastable state may also be produced by sudden solidification from the liquid state. Even when solidification is complete, during subsequent slow cooling molecular rearrangement among the different constitutents or phases may occur, and these changes may make either for greater or less hardness of the aggregate in whole or in part.

Mr. J. C. W. HUMFREY, of Sheffield, read a paper on "The Part Played by the Amorphous Phase in the Hardening of Steel."

The conclusions arrived at in the paper may be summarized as follows:

The hard structure which can be produced in carbon steels by quenching and in certain alloy steels by normal cooling, is due to the presence of a hard amorphous solution of α iron and iron carbide, which solution may be compared to Beilby's amorphous phase formed by overstrain.

To explain the formation of this amorphous phase the author advances a theory that the passage of a substance from one allotropic modification to another of different crystalline form involves the temporary formation of an amorphous state, corresponding to the liquid phase of the modification about to be formed. In steels such a change occurs at Ar 3; and if, due to sudden cooling or to the presence of certain alloyed elements, the change-point is lowered to a temperature below that at which crystallization in the viscous mass becomes difficult, then the amorphous form will be retained in a metastable form in the cold.

The theory is supported by evidence derived from the micro-structure and physical properties of carbon steels hardened by quenching, and of alloy steels which attain a hard structure even when slowly cooled.

Professor C. A. EDWARDS, of Manchester, read a paper on "The Hardening of Metals by Quenching."

Steels not being the only metals which can be hardened by quenching, must be regarded merely as the higher members of a group of alloys which undergo similar changes, namely, undergo decomposition at certain critical temperatures, during which evolutions of heat occur. The critical heat changes are probably a result of the quick cooling, for if this be increased the temperature at which the changes occur is lowered and their thermal magnitude decreased; in other words, there is an increased tendency to prevent the inversion and keep the heat of the carbide change inside the cold material. Can the highest obtainable rates of cooling completely suppress the heat change? The experiments of Benedicks point in this direction and lead to the view that hardening is caused by the suppression of the heat of the carbide inversion. It has been objected that the structures of quenched steels do not support this view, but Carpenter and the author consider these to be a result of the internal stresses set up and not to indicate a difference in physico-chemical constitution. Thus the hardness produced by quenching is brought about by crystal twinning and possibly direct slipping, and the resulting formation of amorphous layers. The author meets Rosenhain's objection that the stresses set up cause no serious flow or movement in the quenched steel. He points out that Harniot has considerably increased the hardness of cylinders of silver by pressure alone without any apparent deformation. It is unnecessary to suppose with Humfrey that in passing from one allotropic form to another crystals pass through an amorphous stage; if so, where would the energy absorbed come from? On the other hand, if twinning takes place, energy would be absorbed and stored up in the amorphous layers. The facts brought forward by Dr. Desch are considered not to be opposed to the theory of hardening by twinning.

Dr. CECIL H. DESCH, of Glasgow, presented a paper on "The Hardness of Solid Solutions," which was communicated by Dr. T. MARTIN LOWRY.

Any complete theory of hardening must take into account the increased hardness which accompanies the formation of solid solutions (mixed crystals). The hardness of the elements is closely proportional to the internal pressure, a/v_2 in van der Waals' equation, and the hardness of solid solutions has been attributed to an increase in the internal pressure. Native copper has been shown by the X-ray method to have a simple cubic space lattice. Gold and silver are probably quite similar, and the atomic volumes of the two metals are almost identical. It is, therefore, difficult to see how any considerable distortion of the space lattice can occur when the two metals are alloyed. The density is unchanged by alloying, and the metals interpenetrate freely by diffusion, but the hardness is twice as great as that of the single metals. Transparent isomorphous mixture of salts may be obtained without optical evidence of internal strain, and yet exhibit increased hardness. A great difference in the attractive forces between the atoms is not easily conceived in the simple case of silver and gold. No theory at present accounts satisfactorily for the facts.

Dr. CECIL H. DESCH also contributed a note on "Crystal Twinning and the Martensitic Structure."

The theory that the hardness of quenched steels and other alloys is due to repeated twinning is open to serious objections. It is shown that a twinned martensitic structure may be obtained in metals and alloys which are not hard. A very slowly cooled low-carbon steel, previously overheated, showed a characteristic martensitic structure in pearlite of the usual hardness. The hard constituents of quenched alloys may or may not exhibit twinning, and the latter is at most an accompaniment, not a cause, of the hardness.

Mr. ANDREW MCCANCE, of Glasgow, contributed a paper on "The Interstrain Theory of Hardening," which was read in abstract by the secretary.

Only two real allotropic forms of iron exist—gamma iron, which can dissolve carbon and is non-magnetic, and alpha iron, which does not appreciably dissolve carbon and is magnetic at ordinary temperatures. "Beta iron" is only alpha iron which has lost the property of ferromagnetism from purely thermal causes, and the pseudo-change-point at A2 is due to a variation in the specific heat which always accompanies this transition. Gamma iron cannot be made ferromagnetic by any treatment such as permanent deformation, etc. Metals

after deformation are best described as being in a condition of "interstrain," since there are facts which cannot be explained by the theory of a hard amorphous vitreous phase, such as the dissimilarity in magnetic properties of strained gamma and strained alpha iron and the hardening effect on metals of high fluid pressure without any resulting deformation. Hardening by deformation results from purely structural causes which affect the crystalline state.

In steels during cooling two transformations can take place: (*a*) the change in the iron from gamma to alpha, and (*b*) the change in the state of solution of the carbon. Quenching suppresses (*b*) but allows (*a*) to proceed, and the alpha iron formed under this condition is interstrained and hard. This accounts for the magnetic properties of quenched steels and for the fact that the hardness reaches a maximum independent of the carbon content. Austenite, which is soft, results when both transformations are suppressed, but when tempered at about 250° C., or immersed in liquid air, the transformation from gamma iron to alpha takes place suddenly and an increase in hardness corresponds with the formation of the interstrained alpha iron.

Professor HENRY M. HOWE, of Columbia University, contributed to the discussion a paper on "Hardening with and without Martensitization," which was communicated by the president.

Of the six methods of hardening according to the author's classification, five are martensitizing and one non-martensitizing. The former ways of hardening are (1) that of carbon steel by rapid cooling; (2) that of steels with an intermediate proportion of manganese or nickel by air or other moderately slow cooling; (3) that of Maurer's austenitic manganese steel by cautious reheating; (4) that of 25 per cent. nickel steel by liquid-air cooling; (5) cold deformation of any ductile metal. The non-martensitizing way of hardening is holding manganiferous ausentie (Hatfield's manganese steel) shortly below the transformation range (e. g. at 550°), whether the cooling thence be fast or slow. It is shown how all these methods of hardening but the last can be explained by the amorphous theory. This is described as referring the hardening to the presence of a very great proportion of iron made amorphous by the formation of innumerable slip bands, caused by the sudden expansion due to the starting of the $\gamma \rightarrow \alpha$ transformation at innumerable nuclei, and its arrest by the pressure thus caused. The martensitization which occurs in all these cases (formation of the very hard acicular constituent known as "martensite") tallies with the conception of innumerable slippings. The amorphous theory cannot explain the sixth method of hardening (if this also takes place in the absence of carbon—this is being tested), because at such high temperatures amorphous iron should be able to recrystallize. The γ theory, which ascribes hardness and brittleness to martensite because it is an undercooled solution of γ in α, is shown to be unsatisfactory in all of the six cases. If hardening No. 6 takes place in the absence of carbon, the author considers the β (an alleged intermediate allotropic modification of iron) more credible than the amorphous theory, in spite of the surprising slightness of the discontinuity in the cooling curves at the supposed β-α transformation point.

Dr. T. M. LOWRY and Mr. R. G. PARKER presented a "Note on Metallic Filings."

They suggested that these were probably cold-worked in an extreme degree. They regarded the remarkable properties of fresh filings of the silver-tin "dental alloy" as due to the presence of a large proportion of Beilby's amorphous phase. The change of density produced by "ageing" these filings at 100 deg. C. is larger than in the case of pure metals, but experiments now in progress have shown that other metallic filings exhibit analogous changes of density when annealed at 100 deg. or even at 80 deg. C. These temperatures are much below those given by Beilby for annealing temperature of hard-worked alloys, and are very much below the annealing temperatures commonly used in metallurgical work.

Dr. J. E. STEAD, in a communication made by the president, stated that in his opinion we had not sufficient data on which to found any definite conclusion as to why steel is hardened by heating to above Ac 1-2-3 followed by quenching, but it was certain that the carbon was mainly responsible. The different behaviour of hardened and annealed steel when treated with chemical reagents proved that there was a difference in their chemical constitution. The allotropic theory could only be regarded as a tentative hypothesis. The solid solution hypothesis too might be one of several pointing in the right direction. The internal stress hypothesis also might be more or less correct, but it must not be forgotten that 0.9 per cent. carbon steel could never be made intensely hard merely by stressing and distorting in the cold. Again, iron saturated with 1.7 per cent. phosphorus, the phosphorus in this case being in solid solution Fe_3P in iron, is difficult to drill, while Cleveland pig, or any grey iron containing even 2 per cent. or more phosphorus, in which case the Fe_3P is in a free state, can be readily machined.

Dr. Stead opposed the view that twinning was an indication of hardness, nor did he consider that martensite probably consisted of a mass of twin laminæ. The same steel containing 0.9 per cent. carbon, whether quenched from 750 deg. C. and barely martensitic or quenched from 900 deg. C. with a pronounced martensitic structure, is equally hard, in spite of the fact that the internal stresses in the second case must be much the greater.

In conclusion, although we had not sufficient data on which to base dogmatic conclusions, there could be little doubt that on the carbon condition mainly depended the extreme hardness of steel.

Mr. ANDREW MCCANCE in a written communication emphasized the difficulty of explaining the hardness produced without deformation by the action of high pressures on metals, and the magnetic properties of strained α and γ iron, by Dr. Beilby's theory of the amorphous phase. Again, had it been shown experimentally that the amorphous state was actually harder than the crystalline for any substance at the same temperature? Mr. McCance also dwelt on the difficulty of correlating magnetic properties with the amorphous phase theory, and he criticized the way in which Mr. Humfrey met the difficulty by assuming that in the crystalline space lattice it was the *molecules* which were regularly spaced. Mr. Humfrey's view that structureless martensite was formed when all the austenite had been transformed to amorphous α iron, while the more prominent structure obtained from a higher quenching temperature was due to the retention of much austenite, was not in accordance with experimental evidence.

The president, in opening the general discussion, was pleased to notice that Dr. Stead emphasized the fact that the main factor in the question of the hardness of iron alloys was the presence of carbon. It was also evident that Professor Howe, who had kindly sent a communication all the way from America, was also coming back to a carbonistic theory. Sir Robert Hadfield felt so strongly on this matter that he had offered a research prize of £200 in order to stimulate the study of the carbides of iron and of iron alloys generally.

Professor T. TURNER said that the subject under discussion was of extreme importance. Sometimes we required a metal to be soft, and sometimes its value de-

pended on its being hard; we therefore want to know the reason why it is hard or not hard. He agreed with Dr. Beilby that we should know more of the molecular structure of the metals. There were two kinds of hardness which should be kept distinct from each other in one's mind. One was the hardness caused by mechanical deformation, and the other was the hardness brought about by a chemical change which produced a closer packing of the molecules of the material. Still it must be borne in mind that when a metal is hardened its density increases to only a very small extent. Another thing which altered molecular distance and produced hardness was the formation of solid solutions. There must be enormous forces brought into play when one substance dissolves another, and it is natural to assume that closer packing of the molecules results. Professor Turner explained most of the changes in hardness which took place in various steels by the solution or the segregation of the various carbides at different temperatures.

Dr. W. H. HATFIELD pointed out that at least three of the theories brought forward that evening were really an indirect result of Beilby's work on the amorphous theory. Dr. Hatfield had independently arrived at views similar to those of Mr. Humfrey. It seemed obvious that when γ iron changes to α iron it passed through the mobile or amorphous phase; but during quenching the amorphous phase was presumably side-tracked and remained unchanged, thus producing hardness. Dr. Hatfield pointed out objections to his and Mr. Humfrey's views.

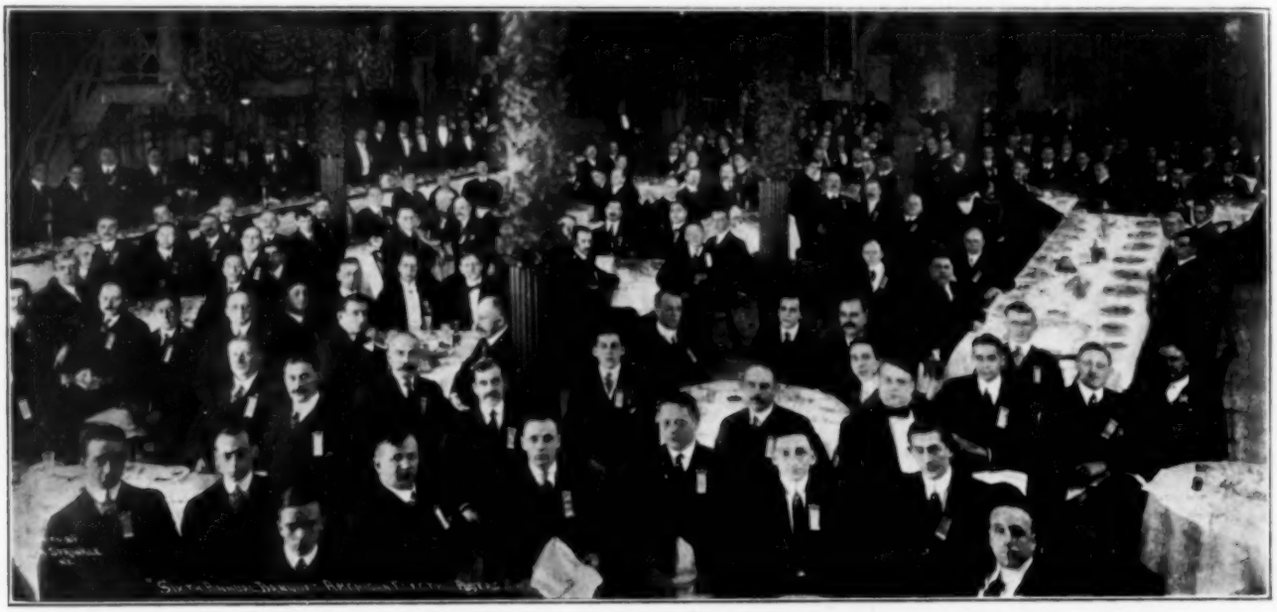
Mr. T. G. ELLIOTT was glad to observe a revival of interest in carbon as a factor in the cause of hardness, and expressed the view that an examination of steels under heat treatment would throw great light on the subject.

Dr. F. J. BRISLEE asked Dr. Beilby whether the passage from the amorphous to the crystalline stage would have a definite transition point, and whether, in the case of aluminium, this point was identical with the annealing point.

Mr. S. A. MAIN pointed out that the various theories advanced that evening were qualitative rather than quantitative. What was badly wanted was a definite scientific unit in which to express hardness, especially extreme hardness.

Sir T. K. ROSE asked Professor Edwards about the production of twinning in tin by bending. "How long did he leave the tin before examination"? He asked this question because tin anneals itself at the ordinary temperature in 24 hours.

The president, in reply, agreed with Mr. Main's view that a definite scale of hardness, which was independent of any particular method of estimation, must be arrived at. He mentioned that when measured by the rebounding test quartz was the hardest material known. Many of the theories advanced that evening must be wrong, because they required that the projectile of a 15-in. gun, which weighed a ton and had a glass hard surface, was in a state of strain. This was improbable, as the projectile could cut through 15 in. of steel without being fractured.



DINNER OF AMERICAN ELECTROPLATERS' ASSOCIATION

American Electroplaters' Society

The New York and Newark branches of this flourishing society held their sixth annual banquet at the Broadway Central Hotel, New York City, on the evening of February 20. Two hundred were present. Mr. de Joannis, editor of *The Brass World*, presided as toastmaster. Prof. J. W. Richards, of Lehigh University, honorary member of the society, charged the electroplaters with being "The Daddies of Electrometallurgy," and proved his thesis by referring to the development of electrometallurgy from the electroplating art. Mr. A. K. Selden, of the Crocker-Wheeler Electric Company, described the characteristics of "The Modern Dynamo." Dr. Hiram Lukens, of the Harrison Laboratory, University of Pennsylvania, described briefly the electro-analytic methods which platers can use to determine the metal content of their solutions.

The society has 14 branches and over 600 members. Its members are chiefly foreman electroplaters, and the society has been of great educational value to them. Mr. Walter Fraime, of Dayton, Ohio, is secretary, and the next meeting will be at Dayton, in the plant of the National Cash Register Company the first week in June. Everybody interested in electroplating is invited to attend the meeting.

At the meeting of the Newark Branch, March 19 next, Prof. J. W. Richards will lecture on "The A. B. C. of Electroplating."

Annual Meeting of American Institute of Mining Engineers

The 110th meeting of the American Institute of Mining Engineers was held in New York City from Monday to Wednesday, February 15 to 17, 1915.

The business meeting was held in the morning of Tuesday, with President B. B. THAYER in the chair. The various reports were submitted and accepted. The results of the annual election of officers were announced as follows:

Mr. WILLIAM L. SAUNDERS, president of the Ingersoll-Rand Company of New York City, is the new president of the Institute. Mr. Charles F. Rand, president of the Spanish-American Iron Company, and Mr. Benjamin B. Thayer, president of the Anaconda Copper Company, are the past-presidents on the Board. Messrs. Sidney J. Jennings and Philip N. Moore were elected vice-presidents. It was announced that the proposed amendments to the constitution had been adopted by a majority of almost four to one.

The feature of the social functions was the annual dinner, held at the Hotel Astor on Tuesday evening. It was exceedingly well attended, some 300 members with their ladies being present. The feature of the after-dinner speeches was the brilliant address of the president, Mr. B. B. Thayer, who reviewed the past year's work in the Institute, announced that Professor James F. Kemp had been elected an honorary member of the Institute, and introduced the new president, Mr. W. L. Saunders, as toastmaster. Speeches were then made by Mr. Gans S. Dunn, Mr. Job Hedges, Dr. R. W. Raymond and Mr. John C. Montgomery.



W. L. SAUNDERS, PRESIDENT AMERICAN INSTITUTE OF MINING ENGINEERS

Professional sessions for the reading and discussion of technical papers were held in the forenoons and afternoons of the three days, often two sessions simultaneously in adjoining rooms of the Institute's headquarters. All were very well attended. In the following report chiefly those papers which are of metallurgical and chemical interest, are noted.

Safety and Sanitation

The first meeting, on Monday morning, was devoted to safety and sanitation. Mr. Arthur Williams, of the New York Edison Co., presided. The four papers presented were: "Safeguarding the Use of Mining Machinery," by Frank H. Kneeland; "Safety Methods and Organization of United States Coal & Coke Co.," by Howard N. Eavenson; "Housing and Sanitation at Mineville," by S. Le Fevre; "Enlarging the Worth of the Worker and the Perspective of the Employer," by J. Parke Channing.

Iron and Steel

At the iron and steel session, held in the afternoon of Monday under the auspices of the Iron and Steel Committee, Dr. Albert Sauveur, of Harvard University, presided.

High-Blast Heats in Mesaba Practice

A paper on "High Blast Heats in Mesaba Practice," by WALTHER MATHESIUS, of the Illinois Steel So., South Chicago, Ill., was presented, in the absence of the author, by Mr. W. A. Forbes. The use of high blast heats on furnaces melting Mesaba ores is still the exception, the average blast temperatures carried on Mesaba stacks seldom reaching 1100 deg. F., while a large number of Mesaba furnaces have been and are operated on very low blast temperatures, ranging between 800 deg. and 1000 deg. F.

"Actual practice in recent years has proved a different conclusion, having shown that a considerable coke saving is still obtainable when the heats are raised above the 1100° line . . . During the last year, the blast temperatures of two of the Bessemer furnaces at the South Chicago plant of the Illinois Steel Co. were raised above the 1100° line, and for many months temperatures from 1100 to 1300° F. were employed, with the result that the coke consumption was reduced to extraordinarily low figures without causing any operating difficulties . . . Since it has been shown, therefore, that with proper furnace conditions it is not only possible, but profitable in coke economy, to carry high heats on Mesaba furnaces, the next problem is to generate these heats in the most efficient way, and without losing through inefficient stove operation the advantage thus to be gained. In other words, the problem of adapting furnace lines, raw materials, and operation to the new practice having been proved capable of solution, efficient heat generation, through suitable stove construction and operation, is of paramount interest to-day."

The author then discussed the provision of new stove equipment. The erection of a fifth stove is thought by many blast-furnace managers the best means of increasing stove-capacity, for two obvious reasons: (1) because it can often be done with practically no other changes to existing equipment, and (2) because it insures a greater regularity of blast temperature.

But a fifth stove means not only greater complications of operation, but a loss in efficiency due to the increase of radiating surface. The benefit of the regular maintenance of higher heats is obtained at the expense of stove efficiency, because the chief evil has not been removed, namely, the accumulation of flue dust in the stove checkers, which constitutes the greatest impediment to efficiency in stove practice. The only way to eliminate this definitely is to prevent the flue dust from entering the stoves, *i.e.*, to wash the gas thoroughly. In Mesaba practice the washing of the gas is especially important.

"It is the use of washed gas which has made possible the construction of stove linings with a view to stability and heat economy only, and without regard to the consideration of stove cleaning, which, if the gas be dirty, must become the prime factor in determining the checker-work construction. The checker openings, which, where unwashed gas is used, are usually 9 in. square, can, with washed gas, readily be reduced to as small a size as the draft will allow. The checker walls, which, with unwashed gas, are not considered

safe when less than 3 in. in thickness, can now be reduced to the limit set by the size of checker openings as determined by the proper relation of total brick volume to surface, and by the ability of the brick manufacturer to produce a strong, substantial firebrick. In this way, the heating surface of the checker work is increased, for instance, more than 50 per cent. by reducing the checker openings from 9 to 4 in., and the thickness of the checker walls from 3 to 2.5 in. At the same time, this construction eliminates the dead portion of the brick work, in the center of the thicker checker walls, which does not participate in the heat exchange, as is proved by the fact that during the ordinary heating and blowing periods it undergoes hardly any change of temperature.

"By using washed gas and changing the stove linings along the lines indicated above, any furnace plant can increase the heating capacity of its stove equipment without adding to the radiating surface. In many cases an increase which will fully meet all heat requirements can thus be obtained.

"With higher stove temperatures, better insulation of the stove shell gains importance. It can be obtained by making the outer brick walls thicker, and using for them two kinds of brick: a porous kind of highly insulating quality, next to the shell; and, inside of this, a course of common firebrick (except in the combustion chamber, where a lining of highly refractory brick is required). Under no circumstances should the depth of the insulating wall be sacrificed to the desire of increasing the heating surface. To get an idea of the heat saving which can be expected from a better insulation, one has only to consider that in most stove plants the radiation losses amount to fully 20 per cent. of the total heat generated.

"If sufficient heating capacity cannot be obtained within shells of a given size, the only remedy is to enlarge them, by increasing either the height or the diameter. In building new stoves a larger diameter should be chosen; and on existing units an increase in height is generally feasible and sufficient.

"With proper equipment and clean gas, stove operation becomes an entirely different problem. It is no longer largely a question of crowding as much gas and air into the stove as possible. The scientific rules of combustion can now be applied, and the stoves can be heated with a minimum amount of gas by complete combustion, proper draft regulation, and an even distribution of the combustion gases and air over the entire heating surface."

The author then discusses the combustion of washed gas and the distribution of the gases and gives in the final part of his paper a very interesting thermal analysis of the performance of No. 4 Blast Furnace at the South Works of the Illinois Steel Co. during the month of June, 1914.

The weight of materials passed through the furnace was burden 31,645 tons, limestone 6154 tons, coke 13,006 tons, product (including scrap) 17,319 tons, slag 7,811 tons, flue dust 691 tons, blast (excluding moisture) 51,592 tons, moisture in blast 539 tons, top gas (excluding moisture) 72,360 tons, moisture in gas 4,665 tons.

The final heat balance sheet is given in Table I.

Table I.—Heat Balance Sheet for One Ton of Product

Generated

By	B.t.u.	Per Cent
Combustion C to CO	3,995,000	31.1
Combustion C to CO_2	6,754,000	52.6
Hot blast (heat content)	2,057,000	16.0
Moisture of the air in hot blast (heat content)	42,000	0.3
Total	12,848,000	100.0

Consumed

By		B.t.u.	Per Cent
Reduction of Fe_2O_3	6,133,300		
Reduction of Fe_3O_4	490,000		
	6,623,300		
Reduction of MnO	48,400		
Reduction of P_2O_5	17,000		
Reduction of SiO_2	418,500		
		7,107,200	55.3
Calcination of carbonates		702,000	5.5
Dissociation of moisture in blast		397,000	3.1
Carried off with the iron		1,142,500	8.9
Carried off with the slag		909,000	7.1
Carried off with the dry top gases		752,400	5.9
Carried off with the moisture in top gas		700,100	5.4
Radiation, cooling water, and unaccounted for		1,137,800	8.8
Total		12,848,000	100.0

The paper was discussed by Mr. J. E. Johnson, Jr., Dr. J. W. Richards, and Mr. W. A. Forbes and considered to be a highly valuable contribution to the metallurgy of iron.

Finishing Temperature of Rails

A paper by W. R. Shimer, on the "Effect of Finishing Temperatures of Rails on Their Physical Properties and Microstructure" gave a summary of the results of experiments conducted by the Bethlehem Steel Co. during the past year.

The rails were rolled from reheated blooms. All the rail blooms were charged hot in a reheating furnace and brought up to about the original ingot-rolling temperature before rolling into rails. These rails gave better results in deflection, withstood a greater number of drops before breaking, and showed greater ductility than rails of identically the same composition and section which were rolled direct from the ingot.

The results of the very numerous tests are given in tables and the paper is profusely illustrated with microphotographs. While the results as to the advantages of reheating blooms on the properties of the rails seem conclusive, there are no conclusive results as to the best finishing temperature.

"There was a variation of 500 deg. F. in the finishing temperatures and a variation of 1.34 in. in shrinkage. Even with this wide range in temperature and shrinkage, it was impossible to determine, from the results of the respective tests, at what temperature a rail should be finished in order to obtain the best results, since all the tensile and drop-test results recorded are good, and practically identical. The results show it is equally impossible to decide what microstructure and shrinkage are desirable.

"Further, from the results of this investigation we have learned that rails rolled from reheated blooms are more ductile than those rolled direct from the ingot, regardless of their finishing temperature. Also, we have learned to be cautious with regard to judging from the microstructure as to the temperature at which a rail was finished and to be careful in drawing conclusions from the microstructure, alone, in rail-failure investigations. The microstructure appears to be controlled more by the rate of cooling from above the critical point than it does by the temperature at which it was finished. In regular practice rails cool uniformly, since hot rails are going to the bed continually, and therefore the microstructures do not vary as much as they have in this experiment."

Mr. W. R. Shimer's paper was discussed by Mr. Wm. R. Webster, Prof. Henry M. Howe and Dr. J. K. Burgess.

Sound Steel Ingots and Rails

A paper by Dr. George K. Burgess, of the Bureau of Standards, Washington, D. C., and Sir Robert A. Hadfield, of London, England, reported tests of rails rolled in one mill according to American practice, from eight ingots manufactured by the Hadfield special-feeding process (this journal, Vol. 11, p. 79, 1913), and a comparison ingot, supposed to represent the usual type of ingot from which rails are made in this country. The results are given in tables and diagrams in considerable detail.

"The examination of the split ingots shows the great superiority of casting large end up and feeding by the Hadfield special process, such an ingot being physically sound and uniform throughout and practicaly free from chemical segregation.

"The examination of the rails shows that for ingots cast by the Hadfield process, those cast large end up will give rails of uniform quality free from flaws of all kinds; those cast small end up may show a soft region in the web of the *A* rail but are otherwise sound. Those cast in the ordinary manner from piping or otherwise unsound steel may or may not give sound rails, depending upon the condition of the steel.

"In addition to the certainty of producing all sound rails by the special-feeding process from ingots cast large end up, there is a great saving in metal and a consequent increase in percentage of sound ingot available for rails—in these experiments an average of 90 per cent. for ingots Nos. 2, 3, 4, as compared with about 50 per cent. for the piping ingot and an uncertain amount from the rising type.

"The usual physical and chemical tests do not appear to give an adequate measure of the quality of rails. For example, the results of the tensile and drop tests and chemical analyses would not separate the sound from all the unsound rails here examined.

"The question may be asked, Is it not worth while to use, in the manufacture of rails, only sound steel which is cast and rolled in such a manner as to make practically every rail a sound and safe one? We believe this can be done without excessive cost."

The paper was discussed by Dr. Sauveur, Dr. Howe, and Mr. Hibbard. Dr. Sauveur spoke in high praise of the work of the Bureau of Standards and emphasized that if there is a method to make sound ingots, the ethical standpoint should not tolerate the use of unsound ingots for rolling rails. On the other hand in a discussion by Mr. F. W. Wood, it was stated that not all defects were eliminated by the Hadfield method, such as surface flaws and slag inclusions, so that it was still an open question how far rail failures could be avoided by the Hadfield process.

Other papers presented at this session were:

"Modern Gas-Power Blower Stations." By ARTHUR WEST, of the Bethlehem Steel Co. It was profusely illustrated by lantern slides and the possibility of an accurate measurement of the air (far superior to the use of Pitot tubes, etc.) was emphasized.

"Are the Deformation Lines in Manganese Steel Twins or Slip Bands?" By HENRY M. HOWE and ARTHUR G. LEVY. The evidence produced by the authors shows these lines to be slip bands, not twins.

"Structure and Hysteresis Loss in Medium-Carbon Steel." By F. C. LANGENBERG and R. G. WEBBER. In magnetic testing careful attention should be given to the previous history of heat treatment and the resulting internal structure of the metal undergoing test. A mere statement of its conditions as hardened or unhardened, annealed or tempered, is idle and often misleading. It would seem that a minimum hysteresis loss could be obtained by the combination of large grains with coarsely laminated pearlite.

"The Magari Iron-Ore Deposits, Cuba." By JAMES F. KEMP (illustrated by most interesting moving pictures).

American Potash

Simultaneously with the iron and steel session a session devoted to non-metallic minerals was held in an adjoining room. The question of possible American sources of potash was brought up in two papers.

Mr. CHARLES H. MACDOWELL, of Chicago, Ill., in his paper on "German and Other Sources of Potash Supply" referred to the inauguration of the manufacture of commercial fertilizers by Armour & Co. in 1894, his recommendations, and sketched the geology and mining of potash salts in Germany and elsewhere. As to the American possibilities he spoke as follows:

Some potash can be made as a by-product from other manufacturing industries. Practically no progress has been made in this direction in this country.

The sugar-beet tonnage in the United States totals 5,147,000 tons. Sugar-beet wastes from this tonnage could produce 30,900 tons of potassium carbonate, equal to 15,440 tons of pure potash.

Raw wool contains up to 20 per cent. potash salts. The wool clip of the United States weighs 298,000,000 lb. In wool scouring 7,450 tons of potassium carbonate or 4,470 tons of pure potash is washed out and lost. This could be largely recovered. Much raw wool from Australia and other countries is imported, and the potash from the handling of this wool could also be saved.

Potash from Cement Burning.—Many cements before clinkering contain small percentages of potash, say 0.1 to 0.25 per cent. In burning this is volatilized. While the percentage is small, the tonnage is so large it figures quite a production on paper.

Many experiments have been made to recover this volatilized potash. It has been worked out to a point where the physical part of the operation is a success. It consists of condensing the volatilized potash in chambers and dust collectors similar to the bag house used in smelters. Up to the present time, however, no cement manufacturer has produced potash as a by-product. Possibly the investment expense attached to its recovery figures against it. I have no data on this.

The industry is a possible source of a considerable tonnage of potash and in case of necessity can be utilized without any extensive changes in present methods of manufacture. Possibly cheaper recovery methods may be found.

At one time considerable carbonate of potash was derived from the ash from burning cotton hulls. These are now used for fodder, so no potash could be obtained from that source.

A few years ago tobacco stems were distilled destructively for nicotine and other products. The ash from this material contained high percentages of carbonate of potash. This method of handling has now been discontinued, but the potash in the ground tobacco stems is saved and used for fertilizing purposes.

This about exhausts the by-product possibilities as far as I know.

Hard-wood ashes and other ashes are gathered and used in fertilizing for their potash contents. City garbage contains appreciable percentages of potash. This garbage in many cities is recovered and used for fertilizing purposes.

The author then sketched the well known work of Government Bureaus, especially the Geological Survey, the Department of Agriculture, and the Bureau of Mines, and finally summed up as follows:

In by-product lines, the sugar manufacturer and the wool scourer might spend some money on solving their problem. The cement manufacturer could well afford to investigate potash manufacture from potash-bearing rocks in connection with cement manufacture.

If potash is to be produced in this country in quantity, some one must spend some money. There has been a noticeable reluctance on the part of American capitalists to finance serious research work, or prospecting by deep core drilling. To begin with, our mining laws and mineral withdrawal possibilities are discouraging. A German potash mine controls several thousand acres of mineral rights. The necessary capital investment would not be justified if this control was not legally obtainable. Potash mines with the necessary concentrating plants are expensive and a large acreage control is necessary. Deep core drilling or other development work on government lands by private individuals would not be justified during the present stage of development of the art of conservation as practiced by our legislators. A positive control of acreage must go with such preliminary work.

There is a large market for potash and the demand is growing. Possibly the lever of necessity may develop sufficient power to overcome the prevailing inertia. Up to now Searles Lake is the only nearby producer on the map.

Dr. WILLIAM B. PHILLIPS, Director of the Bureau of Economic Geology and Technology of the University of Texas, in a paper on an "Investigation of Sources of Potash in Texas" comes to the conclusion that the only hopeful outlook for the existence of workable beds of potash salts in Texas is in the direction indicated by Dr. J. A. Udden* in connection with the deep well at Spur, Dickens County, and in the almost wholly unknown region southeast of and bordering on New Mexico. Explorations in either of these areas would have to be in depth, with systematic chemical examination of cuttings and return waters.

White-Burning Clays

A paper by Dr. JOEL H. WATKINS, of Washington, D. C., on "White-Burning Clays of the Southern Appalachian States" dealt chiefly with the North Carolina, Virginia, and Georgia kaolins or china clays (residual); the South Carolina and Georgia kaolins or paper clays (sedimentary), and the Florida and Tennessee plastic kaolins or ball clays (sedimentary).

The economic aspects were sketched as follows:

In 1913 the United States produced white-burned products which had a total value of $31,443,450, and in the same year imported white-burned ware valued at $9,340,890. The total export of white ware from the United States in 1913 was valued at $149,281; thus showing that the total

*The Deep Well Boring at Spur, *Bulletin* of the Bureau of Economic Geology, University of Texas, No. 363.

value of the white-burned pottery products entered for consumption in the United States in 1913 was $40,635,059.

In 1913, the imports of kaolin or china clay into the United States amounted to 268,666 short tons, valued at $1,623,993, with an average value of $6.04 per ton. According to Parsons, "This kaolin displaced a like amount of domestic raw material which, if properly handled, has no superior." Against this, in the same year, only 197,276 short tons of kaolin and ball clay were produced in this country, which had a total value of $893,259 and an average value of $4.53 per ton. Thus it may be seen that our domestic production of white-burning clays is only equal to about two-thirds of our imports in quantity, and half of our imports in value.

In consideration of the wonderful reserves of high-grade clays in the territory described above, it would seem that the United States, instead of importing annually large amounts of clay, should produce enough to supply her own demands, and even be a competitor in foreign markets. There are several good reasons, however, for this great difference between imports and domestic production, but only reasons which are due to existing conditions, all of which can be easily overcome.

One of the principal objections made by American potters to domestic pottery clays is that the product is not uniform in character, or in other words, has not been properly prepared and classified before shipping. The potter justly demands a uniform product under guarantee, since the slightest variation in his ceramic mixture may cause the entire plant to be shut down until the irregularity is discovered and eliminated. Such variations may be of either chemical or physical character and may result in a lack of sufficient plasticity, a change in color on burning, a change in temperature at point of vitrification, a change in shrinkage, a tendency to warp and crack, and a failure to take the glaze.

To meet the requirements of the potter, therefore, the U. S. Bureau of Mines has wisely advocated a central depot where the output of a number of mines may be properly mixed and graded under the supervision of a trained ceramic chemist. Such a plant, if successfully engineered, should practically eliminate the present practice of mining to-day and shipping to-morrow, and should greatly stimulate the mining of kaolin by smaller operators. The output should demand a higher price than the clay is now bringing, and should capture the trade of our domestic potteries.

Such a plant, or holding company, could be operated successfully not only in the North Carolina residual kaolin district, but also in the South Carolina and Georgia sedimentary kaolin districts.

Another reason why American white clays are not more extensively used is because the clay mines, for the most part, are so remote from the manufacturing centers. Practically none of the white clays now being mined in the Southern Appalachian States are consumed in these States, and the bulk of the product has to be shipped by rail, more than 400 miles in the case of the North Carolina kaolins, more than 600 miles in the case of South Carolina and Georgia kaolins, and more than 700 miles in the case of Florida ball clays. If these clays were properly prepared, and could be sold under guarantee to the pottery plants, there is no doubt that the potter would get closer to the source of his raw materials.

Estimates submitted by a number of clay miners in the North Carolina field show that this material, under favorable conditions, can be produced at a cost ranging from $2 to $4 per ton, and has a selling price of from $8 to $9 per ton at the mines. In the South Carolina and Georgia field estimates were submitted showing a range in cost of production of from $1.50 to $3 per ton with a selling price of from $4 to $6 per ton. The writer was not able to obtain figures on the cost of production of Florida ball clay, but, considering the great thickness of the clay-bearing beds and the economical methods of mining, it would be reasonable to assume that the margins of profit should compare favorably with those of the North Carolina and Georgia mines.

In view of the large amount of white clay consumed by American manufacturers, and the growing demand for domestic clays, it would seem that the clay-mining business in this country is almost in its infancy. Also, a review of the distribution of the clay resources in the United States would point to the fact that America must in the future look to the South for her supply of domestic white-burning clays.

Mining and Milling

The morning session of Tuesday was devoted to mining and milling with the following program:

"Experiments on the Flow of Sand and Water Through Spigots." By R. H. RICHARDS and BOYD DUDLEY, JR.

"Development of the Butchart Riffle System at Morenci." By DAVID COLE.

"The Boulder Batholith of Montana." By PAUL BILLINGSLEY.

"The Main Mineral Zone of the Santa Eulalia District, Chihuahua." By BASIL PRESCOTT.

"Cloncurry Copper District, Queensland." By W. H. CORBOULD.

"Mining and Reduction of Quicksilver Ore at Oceanic Mine, Cambria, Cal." By C. A. HEBERLEIN.

"Metallurgical Practice in Porcupine District." By NOEL CUNNINGHAM.

"An Improved Form of Cam for Stamp Mills." By ARTHUR B. FOOTE.

"Method for the Determination of Gold and Silver in Cyanide Solutions." By L. W. BAHNEY.

Fuels

A technical session on fuels, under the auspices of the committee on petroleum and gas and the committee on coal and coke, was held in the afternoon of Tuesday. Captain Lucas presided.

The feature of the session—and a rather sensational feature—came at the end of the session in form of a paper, not on the printed program, by Dr. Snelling, of Pittsburgh, Pa., on "Synthetic Fuel Oil."

Gasoline from Synthetic Fuel Oil

Dr. WALTER O. SNELLING in his paper on "Synthetic Fuel Oil" sketched the results of an extended research carried out by him in following up a discovery which he made some five years ago. The gist of the very interesting paper is given in the following abstract:

When any hydrocarbon, such as kerosene oil, melted paraffin, vaseline, fuel oil, or any such material, is subjected to the treatment described it comes out after treatment a fluid having the characteristics of crude oil. Even water-white kerosene, after five minutes' treatment, comes out a dark green liquid by reflected light (dark red-brown by transmitted light), and which resembles ordinary Pennsylvania crude oil so perfectly that even an oil expert cannot pick out bottles of the manufactured crude when placed among bottles of natural crude.

This strong resemblance in appearance also extends to marked similarity in composition. When this "synthetic" crude is distilled, it yields gasoline, kerosene, gas oil, and lubricating oils, much as any ordinary crude oil would do.

By this process "synthetic" crude oils have now been made from such dissimilar materials as paraffin wax, kerosene, fuel oil, rod wax, bottom settlings, gas oil and many like substances. In every case the resulting "synthetic" crude oil has resembled natural crude oil and on distillation has been found to yield practically the same products.

Apparently this process discloses certain fundamental principles governing the transformation of hydrocarbon bodies such as has produced crude oil in nature. Apparently it also points out and discloses in a most interesting way the lines of work which must be followed to transform any hydrocarbon into any other hydrocarbon.

Much work has been done by others recently, in attempts to make gasoline from heavier oils. In general, all these processes have yielded light products in some ways suitable for use as gasoline, but having the disadvantage of a marked yellow color, and a bad odor, which could only be removed by treatment with acid, resulting in the loss of a large amount of material.

By the present process, we change any hydrocarbon into crude oil, and this crude oil gives about 15 per cent of absolutely colorless gasoline, without objectionable odor. The residue, after removing the gasoline, can be again put through the same process, when it will give more crude oil, and from this an additional 15 per cent of gasoline can be obtained.

This process can be repeated over and over, and in our experiments up to now we have obtained even from still residue (the very heavy residue remaining after petroleum refining) up to 55 per cent of colorless gasoline of excellent quality. From gas oil we have obtained 60 per cent of high grade gasoline, and from paraffin, 65 per cent of gasoline.

It should be emphasized that in every case the gasoline so produced has not been inferior, yellow, or bad smelling gasoline, but has been gasoline of the very highest grade, free from heavy ends (that is to say, free from products not of the proper gravity) and having an odor not one particle more objectionable than that of ordinary, carefully refined gasoline made in the usual way.

Apparatus and Process.—The present invention rests upon the discovery of the fact that, when any hydrocarbon is placed in a vessel of such size that the hydrocarbon occupies about three elevenths of the total volume, and is under these conditions heated to such temperature as brings about within the vessel a vapor pressure of 800 pounds per square inch, the hydrocarbon introduced into the vessel becomes changed into "synthetic" crude oil. For the best results a very small amount of a suitable catalyst (ordinary graphite, finely powdered nickel, copper, etc.) is added to the oil before the treatment described.

From the experiments made (representing some 2,000 tests) it appears evident that some very fundamental change is brought about in oil when treated in the manner described, and that this change is of so deep-seated an origin as to lead to the general rearrangement and regrouping of the molecules, and leading to the production of new chemical bodies very similar, if not absolutely identical, with the material present in natural crude oil.

It is not yet at all certain that this method is capable of practical application in oil refining, in view of the fact that the pressure employed is quite high for commercial work. On the other hand, the remarkable results obtained are of such nature as to lead without doubt to efforts being made to build apparatus of large size for such work, but the success of these experiments cannot now be foretold.

This research work has been conducted under the financial direction and assistance of Mr. John T. Milliken, of St. Louis, Mo., president of the Milliken Refining Co.

Non-Ferrous Metallurgy

An exceedingly interesting session, from beginning to end, was held on Wednesday morning, under the auspices of the Committee on Precious and Base Metals. Mr. CHARLES W. GOODALE presided during the first half of the session, Mr. E. P. MATHEWSON during the second half.

The first paper was presented by J. B. TYRRELL, of Toronto, Ontario, on "Gold-Bearing Gravels of Beauce County, Quebec," and illustrated by numerous lantern slides.

Chloridizing, Roasting and the Separation of Copper from Nickel

A paper by BOYD DUDLEY, Jr., of Pennsylvania State College, followed on "a study of the chloridizing roast and its application to the separation of copper from nickel." The investigation had been carried out at the suggestion of Professor H. O. Hofman at the Massachusetts Institute of Technology.

The purpose of the work was, first, to study some of the reactions that have been considered as a part of the mechanism of the chloridizing roast, and second, to study the conditions under which nickel oxide and copper oxide may be chloridized. While the production of chlorine gas by various reactions during the chloridizing roast may not be primarily useful in the chloridation of metal oxides and compounds, it nevertheless serves a useful purpose in preventing the dissociation and decomposition of chlorides once they have been formed; for example, the dissociation of cupric chloride into cuprous chloride and chlorine. Therefore it was thought that a study of some chlorine-producing reactions would prove of interest, and the first series of experiments dealt with this phase of the subject. The object of the latter part of the work was to show the possibility of treating heavy sulphide ores, such as those of Sudbury, Ontario, containing much iron and small amounts of copper and nickel, by chloridizing and removing the copper, leaving an iron-nickel oxide product suitable for smelting in the blast furnace for nickel-bearing pig iron. The chloridizing of the copper would, of course, be preceded by a roast for the removal of sulphur, the sulphur oxides being available for the manufacture of sulphuric acid, if under the local conditions this product would be of commercial value.

The author's laboratory experiments, while not permitting a conclusion as to the working of such a process on a large scale, prove the possibility of treating roasted pyritic ores, containing copper and nickel, by chloridizing the copper and leaching it from the iron and nickel oxides, leaving a product suitable to be smelted to nickel-bearing pig iron. The experiments also indicate the temperatures at which the roast should be conducted in order to secure the desired results.

Desilverization of Lead

A paper by F. C. NEWTON, of Maurer, N. J., followed on the "effect of Zn_5Ag_2 upon the desilverization of lead."

Refiners of lead by the Parkes process have always been solicitous of recovering the zinc used in the desilverization, and justly so, as the loss in zinc constitutes one of the heavy costs in this method of refining. Part of this loss is due to the absorption of zinc by lead, and in the present state of knowledge is not recoverable as metallic zinc. The remainder of the zinc, which finds its way into the precious-metal-bearing crust, is recoverable and naturally engages the operators' most exacting attention.

Careful elimination of the impurities in base bullion has enabled the refiner to produce a zinc crust better adapted to retorting, which reflects favorably in the zinc recovery; and to produce a richer crust, thereby lowering the zincking cost, as the increased efficiency of the zinc results in less of it being in circulation.

It is obvious that if the ratio of concentration be increased, a lessening of the amount of crust formed will ensue, throwing less work on the retorts and diminishing the amount of retort metal sent to the cupels, thus making an actual money saving in all these operations.

In the effort to obtain a rich crust, the metallurgist has increased the heat to a considerable degree, upon the assumption that at the higher temperature the zinc-silver alloy could be squeezed free from the adhering lead.

A further possibility for improvement suggested itself in the freezing-point curve of Prof. H. C. Carpenter, upon zinc and silver. Study of this curve disclosed the existence of a definite chemical compound, Zn_5Ag_2, with a freezing point of 665 deg. C., a promising compound for practical application.

In the experiment undertaken it was endeavored to force this compound into the crust, hoping thereby to obtain a higher concentration than formerly. It was recognized that in bringing a large kettle of lead to such a heat, more fuel would be used, the life of the kettle would perhaps be shorter, and other disadvantages would be experienced. As a commercial operation, the project would have to stand on its own feet, so the records were carefully kept to balance the advantages against the disadvantages.

The first experiment, however, showed such refinement unnecessary, as it was conclusively indicated that the melting point of the zinc-silver compound was so modified as to nullify its feasibility as a commercial factor. . . .

In every instance, the crust removed at the highest temperature, that is, just below the freezing point of Zn_5Ag_2, furnished the lowest retort metal. . . .

The tests clearly demonstrated the impracticability of removing the crust at a very high temperature. Further experiments were made to determine what beneficial result, if any, would be obtained by the greater heat. . . . In all cases where the greater heat was used for stirring and pressing, the dross and blue powder formed, especially the former, were far in excess of current practice. . . .

The conclusion to be drawn is, that as a commercial project, the slight increase in doré contents of the crust, which might be obtained from zincking at the greater heat, is more than counterbalanced by the attendant disadvantages. The current practice of to-day, dictated more or less by the question of fuel economy and better life of kettles, has been justified as a practical and efficient procedure from the standpoint of concentration. For comfort of operation, effect upon the men, etc., all arguments are in favor of zincking at a lower temperature.

The paper elicited quite some discussion in which Prof. H. O. Hofman, Prof. J. W. Richards and Mr. W. McA. Johnson participated.

A long descriptive paper by MANUEL EISSLER, of Paris, France, on "Copper Smelting in Japan," was then presented in abstract by Mr. Burr A. Robinson and briefly discussed by Dr. J. W. Richards.

Coal-Dust Fired Reverberatory Furnaces at Copper Cliff and Anaconda

Two very interesting papers on coal-dust fired reverberatory furnaces were then presented. Mr. David H.

Browne, of the International Nickel Company, spoke in his characteristic humorous and modest style on Copper Cliff practice. The paper by Mr. Louis V. Bender, of the Anaconda Copper Company, dealt with the practice at the Washoe Reduction Works.

Mr. DAVID H. BROWNE, in his paper on "Coal-Dust Fired Reverberatory Furnaces of the Canadian Copper Company," gave first a historical sketch and noted the pioneer experiments of S. S. Sörensen at Highland Boy and Charles Shelby at Cananea. The mechanical difficulties encountered by them consisted chiefly of two things, viz.: the stoppage of flues with accumulations of ash, and interruptions and irregularities in the coal-dust feed. These were due to insufficient experience in the preparation and fine grinding of the coal, which is absolutely essential to success.

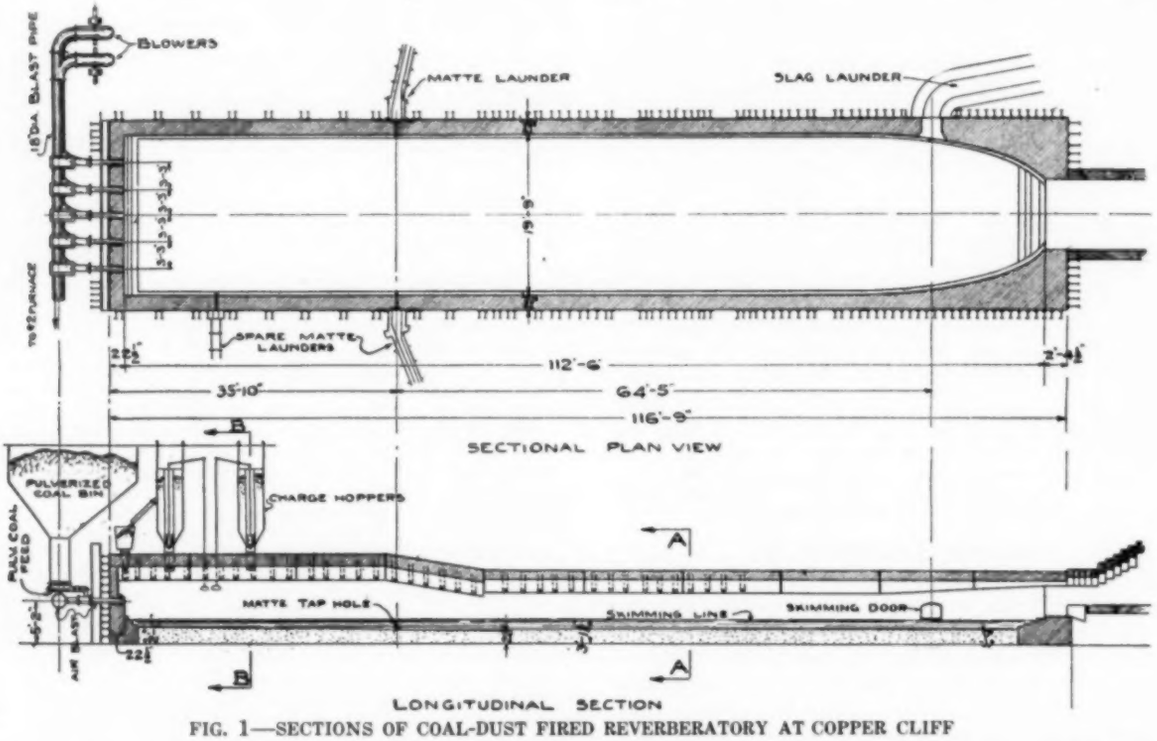


FIG. 1—SECTIONS OF COAL-DUST FIRED REVERBERATORY AT COPPER CLIFF

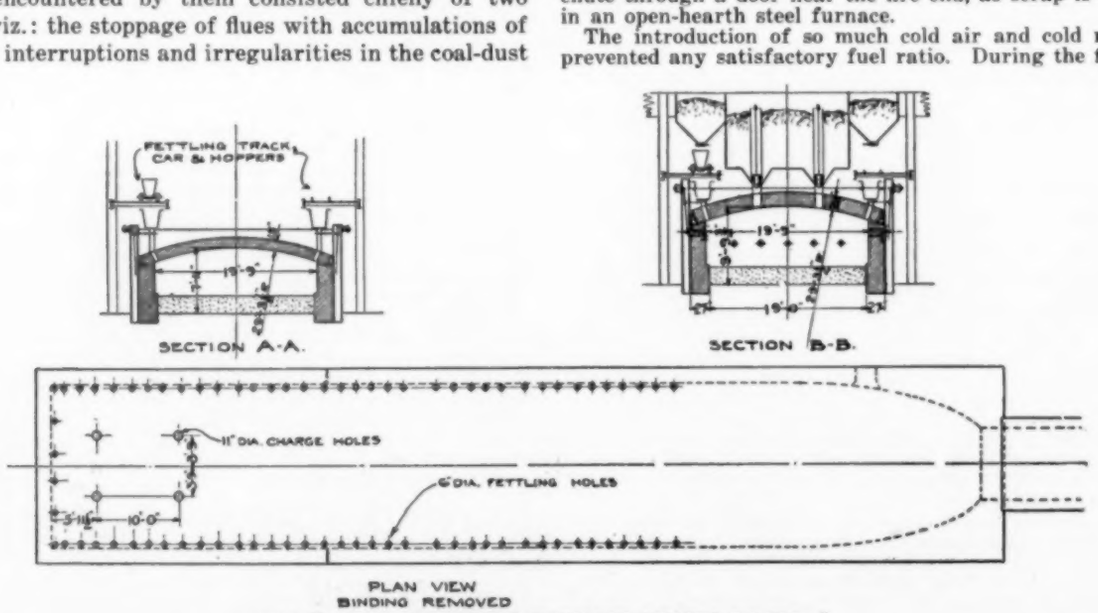


FIG. 2—DETAILS OF THE FURNACE SHOWN IN FIG. 1

In April, 1910, the Canadian Copper Co. authorized construction, and work was begun at once. As the entire site of the proposed plant had to be raised 11 ft. above the yard level, and a large amount of rock cutting and filling was necessary on the hillside where the bins and approaches were planned, active construction of the reverberatory proper was slow, and operation did not commence until Dec. 23, 1911.

As built, the original furnaces were lined with basic brick, and the hearth was an inverted arch of magnesite. The furnaces went into operation before any proper means of drying flue dust was provided, and during the winter of 1911-12 a large amount of the charge, wet and frozen as it came from the piles, was shoveled in through the doors of the furnace. All the converter slag was poured in, at first through an opening in the roof, later by means of an iron chute through a door near the fire end, as scrap is charged in an open-hearth steel furnace.

The introduction of so much cold air and cold material prevented any satisfactory fuel ratio. During the first five months 21,406 tons of cold charge and 43,463 tons of converter slag were smelted with 9,609 tons of coal. This shows a ratio of 6.7 tons of total charge per ton of coal, but only 2.2 tons of cold charge per ton of coal. However, as the cold charge was wet and often frozen, better results probably could not be expected.

The combustion of fuel was satisfactory from the start,

no trouble being experienced either in grinding or burning the coal. The ash, while working on cold charges, choked and clogged the flue at the throat. This difficulty was not eliminated until later, when hot calcines were used and a larger tonnage was smelted. In general, the slower the furnace is worked the colder is the ash and the more it sticks and accumulates, while the faster it is driven the less does the ash hang back in the furnace. Under present conditions, with rapid smelting, the ash is a negligible factor.

In the summer of 1912, the roof and side walls were repaired and some facilities provided for drying the charge. In the winter of 1912, four Wedge furnaces were built to roast green-ore fines. These went into operation in March, 1913. At this date we ceased to send converter slag to the reverberatory furnaces, since with the opening of No. 3 mine the blast-furnace charge became more siliceous and slag could be used economically as a flux.

During this year very pronounced improvements were made by Mr. Agnew, then superintendent of the smelter, who with his foremen, Messrs. Kent, McAskill, and Mason, worked out and adapted to our use a modification of the Cananea system of side fettling. Long and shallow pockets were provided along the side walls, and through holes in the roof green-ore fines were fed to protect the sides. This naturally led to bricking up all the doors of the furnace, and the marked improvement which resulted from the exclusion of cold air and the insulation of the walls by a non-conducting and continuously renewed blanket of fines brought about the extension of this side-fettling system to take in almost the entire charge of calcines.

As the walls were thoroughly protected by the charge thus introduced, the use of basic brick in the walls and hearth was no longer necessary, and the next change, in October, 1913, was to the siliceous bottom and silica brick walls customary in Western smelters.

In 1914, the fuel ratio and furnace practice were steadily improving. The figures for the first three months in 1914, one reverberatory being in use, are given in table II.

In the summer of 1914, a change was made in grinding the ore fines for the Wedge furnace. The ore, which was previously too coarse to make a good calcination, was treated in ball mills, and screened, so that only about 14 per cent. remained on a 20-mesh screen, instead of the former 40 per cent. This finer-crushed ore cannot be produced in sufficient quantity to keep the furnace up to its full capacity. Furthermore, when the calcines dropped, on account of this finer grinding of the ore, from 13 per cent sulphur to 7 or 8 per cent, the production of slag increased and the production of matte fell off. These conditions, with shortage of calcines, militated against the high ratio of charge to fuel and in June, 1914, the fuel ratio was 5.35.

TABLE II. RESULTS OBTAINED AT COPPER CLIFF IN 1914

	January	February	March
Furnace days	31	28	31
Calcines, tons	10,020	9,460	10,860
Blast-furnace, flue dust, tons	906	922	847
Wedge-furnace, flue dust, tons	171	193	180
Converter slag	69	248	0
Green-ore fines and samples	1,731	1,326	2,308
Total charge	12,897	12,149	14,195
Coal	2,575	2,150	2,094
Charge per day	416	434	458
Coal per day	83	77	67
Ratio charge to fuel	5.0	5.65	6.77

The second part of Mr. Browne's paper deals with the design and construction of the Copper Cliff furnaces. These are shown in Figs. 1 and 2 on page 182.

The furnace is fed in a rather peculiar way. When the furnace was started almost all the charge was introduced through two charge hoppers near the fire end, as in the usual Western practice. The first hopper delivered through two openings 11 in. in diameter, 7 ft. 6 in. apart and 8 ft. from the outside of the fire wall. The second hopper delivered through two similar openings 18 ft. from the fire wall.

At present almost all the charge is introduced through hoppers along the side walls. Directly over the side walls, at the fire end of the furnace, large bins are provided, which discharge into small bottom-dump cars. These cars run on 24-in. tracks which are supported from overhead. Under these tracks a long trough extends down each side of the furnace just above the side walls. These troughs are filled from the cars on the track above them. Each trough has openings in the bottom, 2 ft. apart, which openings communicate by a slide gate with 6-in. iron pipes. These pipes pass into holes drilled in the roof bricks which allow the charge introduced through these openings to slide down on the side walls, over which this charge forms an almost continuous blanket. As there are no doors on the furnace, and as the 6-in. pipes are clayed into the openings in the roof, it follows that no air is introduced into the furnace except what is purposely introduced at the fire end.

These pipes form a continuous line of charging holes, which extend the entire length of the furnace. The charge on the side opposite the slag door is fed all the way to the throat. On the slag side it is fed along as far as the slag door and no farther, as the cold air coming in while skimming cools the wall from the skim door to the throat and obviates the necessity of charging beyond this point. Six similar openings are used on the fire wall. . . .

The coal dust is introduced through five pipes, 5 in. in diameter. One of these pipes is on the center line of the furnace; the others are in horizontal line with it at distances of 3 ft. 3 in. from center to center. These pipes are 5 ft. 2 in. above the bottom of the sand hearth, or 3 ft. 2 in. above the top of this hearth. They are about 2 ft. above the skimming line of the charge and the central pipe is about 4 ft. 8 in. below the highest point of the roof.

The coal used in firing is a good quality of slack. Analysis of one lot showed: Volatile matter, 34.70; fixed carbon, 55.40; ash, 9.45; sulphur, 1.30; moisture, 4.31 per cent.

This coal has a thermal value of about 13,500 B.t.u. per pound. It is about ¾ in. and under in size and contains about 7 per cent. moisture. It is dried in a Ruggles-Coles drier, 70 in. in diameter and 35 ft. long. One ton of coal burned on the grate dries 40 to 50 tons of slack coal to about 5 per cent moisture, which falls to 2.4 per cent. moisture after grinding. About 10 tons of slack is dried per hour of running time. The coal is ground in Raymond impact mills. About 95 per cent passes a 100-mesh and 80 per cent passes a 200-mesh screen.

The pulverized coal is sucked by a fan to separators above the roof of the drier building, and slides down into a screw conveyor which delivers it into bins at the fire end of the reverberatory. The dust is fed from these bins by Sturtevant automatic-feed screw conveyors, one for each nozzle, the speed of which can be regulated. These screws carry the dust forward and drop it into the air nozzles about 2 ft. from the point where the nozzles enter the furnace. Any coal-delivery pipe can be closed off by a slide gate, and any screw conveyor can be stopped by disconnecting the bevel gears attached thereto. In this way any desired number of the five burners can be run, and at any desired speed within wide limits. The amount of air delivered to each nozzle can be varied at will or cut off entirely.

As a rule the five burners are in operation. Each delivers about 13.5 tons of coal dust a day or about 19 lb. of coal per minute to the furnace. The total coal blown in is about 67 tons a day.

The dust drops from the conveyors into the air pipes which carry it forward into the furnace. The air is supplied by a 4-ft. Sturtevant fan, running at about 1300 to 1400 r.p.m. The air supplied by this fan is insufficient for the combustion of the fuel. Openings are left in the end wall between the coal burners. These openings are stopped by loose bricks, so that the amount of air is readily controlled. The draft at the fire wall is about 0.25 in. of water and at the throat it has a maximum of about 1.2 in. The combustion is very good. One test made for 10 days (Jan. 9 to 19, 1914) showed the following averages:

Coal consumption, tons in 24 hr	69.7
Gas temperature at throat, degrees centigrade	922
SO_2 and CO_2, per cent	12.3
Oxygen, per cent	6.5
SO_3, per cent	1.14

During this test the average charge was 409 tons in 24 hr. This shows a ratio of 5.9 parts charge to 1 part coal, but much higher ratios have been attained. The average for March, 1914, was 6.84. This coal ratio depends largely upon the composition of the charge and the analysis of the slag produced.

A criticism might be made of the low temperature of the gases at the throat, 922 deg. C. The usual practise in Western smelters is to carry a temperature of 1200 deg. to 1300 deg. at this point, and it might be thought that this low temperature indicated inefficient firing. The fact is that the heat of combustion is utilized in smelting ore along the side walls and consequently the escaping gases, having done more work than is usually the case, are relatively cold. The function of a reverberatory furnace is to melt ore, and not to raise steam, and for this reason the more heat that is absorbed from the coal gases in the furnace, the more efficient the operation and the cooler the escaping gases.

The ash from this coal causes very little trouble in operating. A small amount settles on the slag, but as this slag is high in iron it is not an undesirable feature. A small amount also settles in the flue and a few hundred pounds may stick around the throat. The ash, where exposed to high heat, forms a very light pumice-like fragile mass. The throat is cleaned out daily by opening the door under the flue. During this cleaning the firing is maintained as usual.

The great advantage of coal-dust firing is the absence of the usual breaks in the temperature curve due to grating or cleaning the hearth, and as a consequence a greatly increased tonnage and fuel ratio. The operation of firing, being purely mechanical, comes under the immediate and direct control of the furnace foreman and responds instantly to his regulation. In addition to this, the peculiar method of feeding by almost continuous side charging obviates the breaks in the temperature curve due to charging or ordinary fettling. For these two reasons the chart of the temperature shows an almost horizontal line, rising or falling in almost exact concordance with the speed of the coal-feeding device.

The maximum bath of matte and slag is 22 in. deep. A constant bath of 8 in. of matte is carried. This matte lies 6 in. below the skimming plate, so that after skimming there are 6 in. of slag and 8 in. of matte left in the furnace, making a total minimum depth of 14 in. The skimming door is banked up 8 in. with sand, so that just before skimming the slag is 14 in. deep. As the charge along the side walls occupies a great deal of room there is never at any time more than 40 or 50 tons of slag in the furnace.

In rebuilding this reverberatory, or in designing a new plant, the hearth should be widened to provide for a larger body of matte, which experience has shown to be necessary. As this method of burning coal and of admitting the charge into the furnace bids fair to come into general use it is to be expected that many changes, both in construction and operation, will be introduced. My belief is that reverberatory smelting along these lines will become cheaper than blast-furnace smelting and that a wider range of ores can be used in such a furnace than in the old-style coal or oil-fuel furnaces.

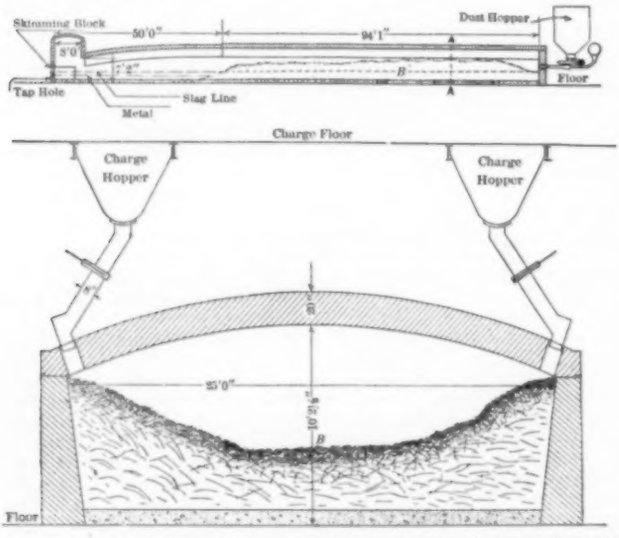


FIG. 3—LONGITUDINAL SECTION AND CROSS-SECTION ALONG LINE AA OF ANACONDA COAL-DUST FIRED REVERBERATORY

Mr. Louis V. Bender's paper deals with "coal-dust fired reverberatories at the Washoe Reduction Works." He describes how after investigating Mr. Browne's work at Copper Cliff, the Washoe Reduction Works decided to experiment with coal dust as fuel in their reverberatories and changed their reverberatory furnace No. 8 to the use of this fuel in June, 1894.

The charging is done on either side of the furnace from longitudinal hoppers, extending a distance of 74 ft. from the back end of the furnace. Leading from the hoppers into the furnace are 6-in. pipes, spaced 19¼ in. apart, through which the charge is intermittently dropped. The charge is kept well above the slag line at all times; in this way the side walls are protected and no fettling is needed on this portion of the furnace. The remainder of the furnace requires fettling. . . .

Conditions which are imperative in order to obtain successful results in coal-dust firing are:

1. The coal, before pulverizing must be well dried, down to 1 cent. or less of moisture. This makes it pulverize better and burn more freely. Nothing is lost in drying it separately, as all the moisture must be evaporated before coal (or any other fuel) will burn, and higher efficiency is obtained when the moisture is driven off before using. The furnace itself is the most expensive place in which to dry the coal, as the effectiveness of the whole fire is lowered by the presence of moisture.

2. The coal must be finely pulverized. The increased surface has a direct bearing upon the efficiency obtained in coal-dust firing. It is well to recognize what this increase is. C. D. Demond, Chief Testing Engineer at the Washoe Reduction Works, says: "The approximate diameter of a 1-lb. lump of bituminous coal is 3 in., and its total surface one-quarter of a square foot, while 1 lb. of coal ground so that 95 per cent. will pass through a 100-mesh sieve and 82 per cent. through a 200-mesh sieve has a total surface of 8000 sq. ft., more or less, depending upon the physical characteristics of the coal, or 32,000 times the area of the single lump."

These figures show that with finer grinding an enormous increase in surface is obtained, and, consequently, an increase in thermal efficiency. At Anaconda the grinding is done so that from 93 to 97 per cent. will pass through 100 mesh and 79 to 82 per cent. through 200 mesh. . . . The standard of approximately 85 per cent through 200 mesh and 95 per cent through 100 mesh is a practicable commercial standard and should be maintained.

3. The delivery of the coal and air to the furnace must be controlled so that the proper quantities of each may be secured. Undoubtedly, the proper method of firing pulverized coal is to admit with the fuel the exact quantity of air required for the results to be attained, and to maintain this relationship as long as results wished for are obtained. We know that in order to get the best heat efficiency from fuel a certain amount of air must be provided for combustion. Any air in excess of these requirements dilutes the gases and lowers the temperature; and insufficient air will burn part of the fuel to CO_2 and part of it to CO, which means incomplete combustion.

4. The coal must contain enough volatile combustible matter to give the required combustion. In cement work coal containing as low as 22 per cent. V.C.M. has been used. James Lord, of the American Iron & Steel Co., recommends 30 per cent as a minimum.

5. The furnace must be properly proportioned, properly equipped, and in good condition.

6. Provision must be made for taking care of the ash formed.

The powdered-fuel equipment at Anaconda is then described and the advantages of powdered-fuel firing are summed up as follows:

1. An increase in tonnage, which makes it possible to smelt the necessary tonnages with fewer furnaces.

2. The efficiency of this method is much greater than that of burning coal on grates. In burning coal on grates, there is a loss in transferring to the hearth the heat generated in the fire box. This does not occur in coal-dust firing, where the combustion occurs over the hearth itself. Another point is that none of the heat is lost in gratings from the fire box. In our practice of grate firing, this loss amounts to something like 10 per cent of the fuel values. The efficiency is greater, due to a uniform temperature being maintained. There are no fluctuations in temperature due to firing cold fuel or to grate cleaning, or to the personal equation of the men firing the furnace.

The superintendent before leaving his work can adjust the feeding of the coal, and by securing this adjustment with a padlock he can be certain that a definite amount of coal will be burned during his absence. If, for any reason, the furnace men need to shut off the burners, they can do so by releasing a clutch; when this clutch is re-engaged, the burner resumes firing at the original adjustment.

3. Higher temperatures than usual can be produced and maintained because the quantity of coal burned can be easily increased, and also, because there is less excess air to be heated. In grate firing 100 per cent excess air is used, while in dust firing only 25 per cent excess air is required. There being a smaller volume of gases, they will remain longer in the furnace, and, consequently, give up more heat to the charge.

4. Less draft is required because there is no bed of coal through which air is drawn. This is an advantage in that less cold air is drawn into the furnace through the side walls.

Details are given of the results of tests made in September, 1914. The fuel ratio was 7.19 (excluding drier coal) and 7.08 (including drier coal). The ash gave very little trouble.

"The efficiency of this method of firing is improving

so rapidly that a paper is almost out of date before it can be read. New records for tonnage and fuel ratio are made almost every day. The average tonnage per day for the past week was 542.7, with a fuel ratio of 7.50."

The paper by R. E. H. POMEROY, of McGill, Nev., was next presented in abstract, dealing with the "reverbaratory smelting practice of the Nevada Consolidated Copper Co." California crude oil is used as fuel. The results are excellent. A longer abstract of this interesting paper is reserved for our next issue.

These papers were discussed together and the discussion was lively and extended. Mr. Mathewson read from a telegram the latest results achieved in Anaconda.

A communicated discussion described the results obtained at the smelter at Garfield, Utah.

Mr. J. B. Herreshoff paid a fine tribute to the bigness of Western smelters, Western men, and Western open-heartedness and gave details of a big reverberatory (with grate firing) in an Eastern copper plant.

Mr. Klepetko suggested that the excellent results obtained were due perhaps more to the charging on the sides than to the use of pulverized coal. While the charging on the side is an important factor, Dr. J. W. Richards pointed out that there is no getting away from the fact that in a grate-fired furnace 25 per cent of the calorific value of the fuel is lost from the fire place; this loss is wiped out by the use of powdered coal.

Mr. Mathewson stated that with their big new reverberatory the expectations were to realize a tonnage of 750 per day with a fuel ratio of 7½. He also exhibited a brick made from the flotation tailings of slimes at Anaconda (70 per cent silicon, 21 or 22 alumina, 1 sulphur, 0.8 lime) and predicted a big future for this brick.

Mr. D. H. Browne emphasized again in his modest way that most of the Copper Cliff success had been due to the work of "the boys" at the smelter.

In the afternoon of Wednesday there was a session devoted to papers on mining and the application of electricity in mines. On the same afternoon a visit was paid by members and their ladies to the Art Galleries of Senator W. A. Clark.

The seventeenth annual meeting of the **Canadian Mining Institute** will be held at Toronto, March 3, 4 and 5, 1915. Headquarters will be at the King Edward Hotel. The provisional program contains some excellent papers relating to mining and metallurgy in Canada.

The **Calumet & Hecla Mining Co.** has just completed the installation of 12 large Hardinge mills in its new White Pine concentrator. Three Hardinge ball mills of the largest size are to be installed in the plant of Moose Mountain, Ltd., at Sellwood, Ontario, Canada.

Messrs. **Chalmers & Williams**, of Chicago Heights, Ill., announce that they have taken over the exclusive rights of manufacture and sale of the Symons disc crushers, Symons fine reduction disc crushers and Symons pulsating screen.

The **Snyder Electric Furnace Company** is the new name of what was formerly the Metallurgic Engineering Company. The business of the company is largely devoted to the building of the Snyder type of electric furnace. Mr. F. T. Snyder is the president, Mr. Carl H. Book, vice-president; Mr. W. K. Booth, secretary, and Mr. F. E. Berggren, treasurer of the company. The office is at 53 West Jackson Boulevard, Chicago, Ill.

The **American Electrochemical Society** will hold its spring meeting from Thursday to Saturday, April 22 to 24, at Atlantic City, N. J.

Recent Chemical and Metallurgical Patents

Iron and Steel

Sintering Apparatus.—Improvements in apparatus for sintering fine iron ore are embodied in a patent granted to STEPHEN A. KROM, of Birmingham, Ala. The invention relates to sintering apparatus of the pan type, in which a charge of ore is ignited and sintered and then dumped by tilting the pan. The object of the improvements is to secure equalization of draft and uniform ignition, and to prevent the accumulation in the bottom of the pan of fine material falling through the grate bars. To this end the pan is constructed with a conical bottom. From the apex of the cone a connection is made by pipe with a tank or receiver; the exhaust fan is connected with the pipe between receiver and sintering pan. The pan is fitted with an air-tight cover, through which the gas burner tubes extend over the surface of the charge from a main or header outside. By this construction even ignition is secured over the surface of the charge, and the suction is uniform by reason of the fact that it is taken from the apex of the cone bottom. Fine particles of ore falling through the grate are directed by the conical bottom and connecting pipe to the tank or receiver. (1,125,125, Jan. 19, 1915.)

Iron-Boron-Carbon-Copper Alloy.—An alloy that is practically non-corrosive and which can be rolled and machined without being annealed, is patented by EDWARD D. GLEASON, of New York City, the patent being assigned to the Neu-Metals and Process Company, of Long Island City, N. Y. The boron is first incorporated in the copper, the boron being in excess of the quantity that will combine with copper, and this boron-copper is added to low-carbon steel. (1,126,629, Jan. 26, 1915.)

Gold and Silver

Slime Filter.—An improvement in vacuum filters or pans of the tray type is patented by WALTER E. TRENT, of Reno, Nev. A transverse vertical sectional view of the apparatus is shown in Fig. 1. It consists of two oblong trays 1 and 2, supported apart as shown and adapted to be turned on a trunnion 8'. Suitable connection is made between the filter frames resting in the pans and a source of vacuum. The filter frames consist of pipes 16 and 16' perforated as shown in 16'. The slime to be treated is delivered to hoppers 11 and thence by pipes which are extending over the surface of the filters. Water spray pipes 20 and 20' are placed as shown. In operation the slime is delivered to the filters and the liquid drawn from the solids, leaving the latter as a cake on the filter surface. Water is then admitted through the spray pipes to lubricate the filter surface so that the cake will slip from the filter when the apparatus is tilted. (1,125,769, Jan. 19, 1915.)

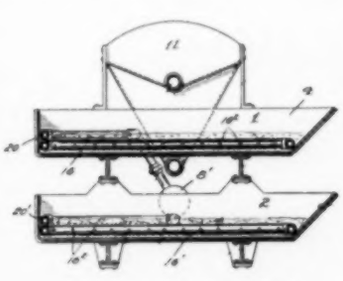


FIG. 1—SLIME FILTER

Precipitant for Gold and Silver in Cyanide Solutions.—A brittle alloy of zinc and sodium, or zinc and any other alkali or alkaline earth metal which will produce brittleness in the resulting alloy, is patented by G. HOWELL CLEVENGER, of Palo Alto, Cal. The patent is assigned to the Merrill Metallurgical Co., of San Francisco, Cal. The alloy thus produced by adding about three per cent sodium to zinc, can be comminuted and used in place of the other forms of zinc

now common in the precipitation of precious metals from cyanide solutions. (1,123,685, Jan. 5, 1915.)

Method of Precipitating Cyanide Solutions.—A method of combining the operations of precipitating and filtering cyanide solutions containing precious metals, is patented by LOUIS D. MILLS, of Johannesburg, Transvaal, South Africa. The patent is assigned to the Merrill Metallurgical Co., of San Francisco, Cal. The apparatus and method is illustrated in Fig. 2. A tank 1 contains filter leaves 2 disposed vertically in the usual manner and having connections with a pump 4 or other means for exhausting the interior of the leaves. The receptacle 14 is for pregnant solution and the ap-

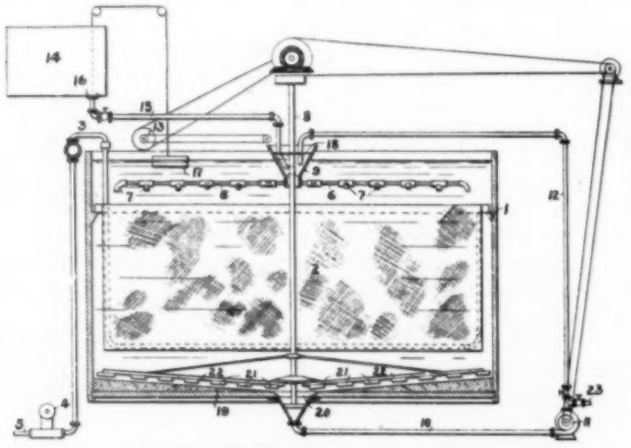
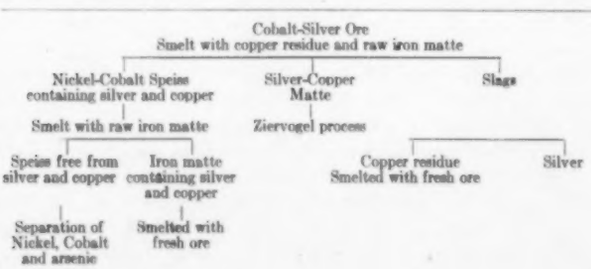


FIG. 2—PRECIPITATING APPARATUS

paratus 13 is a feeder for zinc dust or other mobile precipitant to be mixed with the solution. The solution and precipitant are both delivered into the hopper 9 which is mounted on a revolving shaft 8. From the hopper the mixed solution and precipitant flow through pipes 6 having apertures 7. These pipes also revolve with the shaft and hopper, and provide means for uniform distribution of the mixture above the filter leaves. For the purpose of circulating the solution and precipitant and preventing the accumulation of solid matter in the bottom of the tank, a series of rakes 22 is mounted at the bottom of the shaft 8, similar to the mechanism of a Dorr thickener, and in the course of their revolutions they move any solids toward the central discharge point 20, whence solution is pumped back to the hopper as shown. In operation, the exhaustion of the leaves by the pump 4 causes a cake of precipitate to form on the leaves, and the solution passing through this cake is subjected to precipitating action. When it is desired to recover the cake, the supply of fresh solution is shut off, the pump 4 stopped and the precipitate sluiced from the leaves. It can then be removed from the tank by the pump 11 and pipe 23. (1,123,778, Jan. 5, 1915.)

Treatment of Cobalt-Silver Ores.—According to a process patented by WILLIAM PHILLIPS, of Swansea, Wales, cobalt-silver ores can be treated for the recovery of silver, nickel, cobalt, copper and arsenic. An outline of the process is given below.



The first step is performed in a reverberatory furnace. About 82 per cent of the silver in the ore passes into the copper matte, and about 17 per cent into the speiss. Also about 16 per cent of the copper passes into the speiss. The silver-copper matte will contain between 2000 and 3000 oz. silver per ton and about 25 per cent copper. The silver is extracted by the Ziervogel process.

The first raw speiss is smelted in a reverberatory with raw iron matte, the operation being repeated several times. About 60 per cent of the silver goes into the iron matte in the first smelting. (1,127,506, Feb. 9, 1915.)

Copper and Tin

Electrolysis of Copper Solutions.—A process of electrolyzing copper solutions containing iron, without first reducing the iron to the ferrous state, is patented by N. V. HYBINETTE, of Christiania, Norway. He makes use of a cell containing a diaphragm separating the anode from the cathode. A continuous flow of solution is maintained on the anode side only, and the solution on the cathode side is effected only by such changes as can be transmitted by diffusion. The solution on both sides of the diaphragm may, in the beginning of operations, contain 20 g. of iron as ferrous sulphate, 40 g. iron as ferric sulphate, 40 g. copper as sulphate and 50 g. free acid. When the current is applied the iron in the cathode is reduced and copper begins to plate. If then the solution on the anode side is continuously circulated so as to maintain a uniform composition, the solution on the cathode side will automatically adjust itself to contain say, 55 g. ferrous iron and 20 g. copper. The inventor states that "without any apparent reason copper is entering the cathode compartment, while ferric salts do not enter and the electric energy is therefore used to deposit copper and not to reduce ferric salts." With a concentration of solution mentioned, he uses a density of 10 amperes per sq. ft., and obtains an efficiency of nearly 90 per cent. The voltage is approximately 3. In Fig. 3 is shown a cell for this work; B is the anode and C the cathode, the latter being enclosed in a diaphragm formed of a double-walled leaden screen D secured to a wooden frame K which is filled with asbestos or other porous material. The electrolyte flows in at F and out at G. (1,123,299, Jan. 5, 1915.)

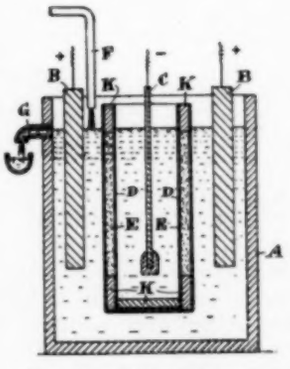


FIG. 3—ELECTROLYTIC CELL

Purification of Copper.—A method of producing pure copper for electric purposes and for the manufacture of copper-clad metals is patented by WM. M. PAGE, of Philadelphia, and WIRT TASSIN, of Chester, Pa. It consists in deoxidizing molten copper at a high temperature by the addition of iron or steel, and later removing the excess of iron by covering the bath with carbon. This has the effect of blanketing the bath with oxides of carbon, both of which are oxidizing to iron but not to copper. The copper, after purification, is cast under conditions which preclude oxidation during the pour. In making copper-clad metal, the metal to be treated is prepared in a special manner and then dipped in the copper. (1,125,164, Jan. 19, 1915.)

Sulphatizing Roast for Copper Ores.—The conversion of copper sulphide into sulphate for purposes of leaching the soluble copper salt, is usually accom-

plished by roasting under certain conditions. According to a patented process of A. D. CARMICHAEL, of West Norfolk, Va., this sulphatizing can be accomplished by first heating the ore out of contact with the air to a temperature between 500 deg. and 700 deg. C., at which temperature the formation of iron sulphate will be avoided, and then exposing the heated ore to air, preferably heated. One advantage claimed is the production of more concentrated sulphurous acid gas, suitable for making sulphuric acid, than can be made by ordinary roasting processes on low-sulphur ores. Other advantages lie in forming no iron sulphate, or in rendering iron insoluble. (1,124,696, Jan. 12, 1915.)

Copper Converter.—An improved form of converter is patented by HERBERT HAAS, of San Francisco, Cal., having for its object the converting of mattes into blister copper continuously instead of intermittently as in present methods. As shown in Fig. 4, the converter consists of a shell lined with magnesite brick. The bottom comprises a central inverted cone or bell portion and a depressed annular portion. In the center of the cone is the tuyere block in which are formed tuyeres that are directed upwardly, outwardly and preferably tangentially. A tap-hole is placed at the level of the depressed annular portion for the removal of molten copper, and an upper tap-hole for the removal of slag. The tuyeres are greater in number, but of smaller cross-section than those in ordinary converters, thus affording more efficient use of air. The function of the depressed annular portion is to store reduced, molten copper and remove it from the action of the blast. (1,123,868, Jan. 5, 1915.)

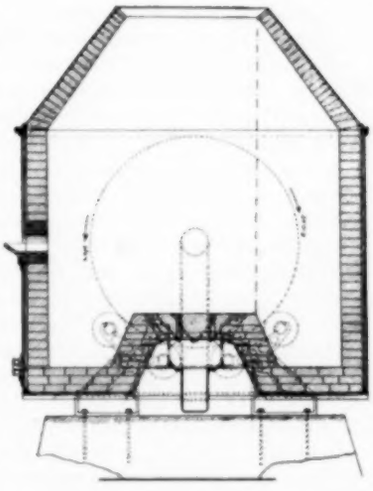


FIG. 4—COPPER CONVERTER

Electrolytic Refining of Tin.—A process of electrolytically refining tin, patented by GEORGES MICHAUD and EUGENE DELASSON, of Montreuil, France, consists in passing a current from an anode of impure tin to a cathode through an electrolyte composed of 100 parts by weight of tin protochloride, 10 of sulphuric acid, 1 of madnesium chloride and 1 of boric acid, mixed with water to make a solution of 20 deg. Baume. The cathodes are formed by copper plates arranged on edge, and upon the upper edges of which the tin is deposited in non-adhesive form and mechanically removed. The homogeneity of the electrolyte is maintained by circulating it through a trough containing tin waste of any kind. The inventors claim that the process will produce 2.22 grs. of chemically pure tin per ampere hour in a more economical manner than with arrangements ordinarily used. (1,124,315, Jan. 12, 1915.)

Uranium, Vanadium and Radium

Treatment of Carnotite Ores.—A method for treating complex carnotite ores for the recovery of uranium, vanadium and radium is patented by CHARLES W. DANFORTH, of Youngstown, O.; WILLIAM P. SAMUELS, of New Castle, Pa., and WILLIAM T. MARTERSTECK, of Youngstown, O. The method consists in giving the ore an oxidizing roast, then adding sulphuric acid to precipitate barium and radium into the residue and dissolve uranium and vanadium. The solution is separated by filtration. The ore is ground to about 40-mesh and roasted in an oxidizing atmosphere at a temperature of 1100 deg. F. for about an hour. The addition of sulphuric acid is said to dissolve about 90 per cent of the vanadium and all the uranium, leaving the barium and radium as sulphates with the sandy residue. To recover the radium, the residue is washed free from acid and treated with a solution of caustic soda and sodium carbonate. This changes the barium and radium compounds into carbonates. The mixture is then filtered and washed, leaving the barium and radium still with the residue. The addition of hydrochloric acid then dissolves the barium and radium. The solution is removed and precipitated with sulphuric acid, the sulphates separated and again converted into chlorides, after which the radium is concentrated by crystallization.

Synopsis of Recent Chemical and Metallurgical Literature

Iron and Steel

Magnetic Habits of Alloy Steels.—There is a certain relationship between the magnetic and physical characteristics of steel and its alloys, distinct similarity between their magnetic and physical behavior. Dr. J. A. MATHEWS, in a very interesting paper (*Proceedings*, American Society for Testing Materials, Vol. XIV, 1914) brings out some interesting new relations and remarks justly that the fascination of magnetic investigations lies in the frequency of unexpected results. He suggests a new magnetic unit of magnetic hardness B_r/H_c; that is, the ratio between residual density and coercive force is used to indicate magnetic hardness in a way similar to the use of μ to indicate permeability. Dr. Mathews discusses the relation between hardness as measured by the Brinnel and Shore methods and magnetic hardness as indicated by B_r/H_c. In hardened alloy steels the magnetic properties vary with the cross-section, but in some cases, the magnetic hardness increases as the section increases while in other cases the reverse is true, and in some alloy steels either condition may be had, depending upon the manner of quenching. Many alloy steels give lower induction, lower residual density and higher coercive force when quenched in oil than when quenched in water; the corresponding physical hardness test showing, as would be expected, that the water quenching confers the greater hardness. The effect of drawing the temper of hardened alloy steels is discussed and it is shown that for equal drawing temperatures the magnetic properties of oil-hardened pieces are most affected, while as to the physical hardness the water-hardened pieces are affected to the greater degree.

Gold and Silver

Metallurgical Practice in the Porcupine District.—In a paper presented at the New York meeting of the A. I. M. E. last month, Mr. NOEL CUNNINGHAM, formerly mill superintendent for the Hollinger Gold Mines, Ltd., discusses the metallurgical technology of Porcupine district ores. His notes supplement milling articles of a descriptive nature, such as appeared in METALLURGICAL AND CHEMICAL ENGINEERING in September and October 1914.

There is no oxidized ore in the district. The precious-metal content is about in the proportion of 85 of gold to 15 of silver by weight. Two classes of ore are distinguished: *Class A*, which is pure quartz with inclusions of schist, containing free gold which is 60 per cent. to 85 per cent. free-milling, spongy and readily soluble in cyanide solution. *Class B*, which is an iron

silicate schist, contains 4 per cent. to 5 per cent. pyrite. This ore produces in grinding a comparatively large amount of non-crystalline slime which is quick settling. The gold is free, but so fine that it will neither amalgamate nor pan; it is disseminated through the rock and not chiefly associated with the pyrite.

After giving a brief outline of the mills, past and present, in the Porcupine district, the author analyzes milling practice and makes some comparisons of methods. In regard to stamps vs. ball mills as crushers preliminary to tube-milling, the author is of the opinion that ball mills are preferable on Porcupine ore. On the subject of stamping in water and amalgamating vs. stamping in solution without amalgamation, the author compares Dome and Hollinger practice, respectively:

"The advantages claimed for stamping in water and amalgamating are a better recovery of the coarse free gold and the saving in treatment cost, due to a smaller amount of solution to precipitate and a smaller amount of precipitate to handle. At first sight it would also appear that a saving in dissolved losses from the filters would be made, owing to the smaller amount of gold in solution going to the filters.

"While at the Hollinger there is a smaller percentage of amalgamable gold in the mill heads than at the Dome, on the other hand, the coarse free gold per ton of ore in the mill heads is about the same due to the fact that the head assay is nearly triple that of the Dome. Hence, if amalgamation is necessary in order to assure the dissolution of coarse gold in cyanide solution, difficulty from this source should be experienced at the Hollinger, where crushing is in solution with no amalgamation.

"This is not the case, however; all the coarse gold goes into solution in the classifier-tube mill closed circuit. This is proved by two facts in connection with the Hollinger operations. Table concentration after fine grinding is practiced at the Hollinger, and any coarse free gold passing the tube mill-classifier closed circuit would be caught on the tables. No coarse gold is present in table concentrates, however, no color of free gold ever showing on the tables; also practically no amalgam was produced (under 1 per cent. of the total values recovered) during six months, pan-amalgamation of concentrates from the tables.

"Facts also indicate that crushing in solution without amalgamation has the best of the argument in regard to amount of solution precipitated and dissolved gold mechanically lost. With the head assay at the Hollinger about three times as high, the precipitation ratio is only about twice that at the Dome, and the mechanical loss of dissolved gold and cyanide only about one-half. Nor is any saving in dissolved losses or treatment cost proved in favor of crushing in water followed by amalgamating. On the other hand, there are added to the treatment cost, (1) cost of amalgamation, (2) cost of increased cyanide consumption due to 'waste' solution precipitated and thrown away, and (3), in winter, the cost of heating to mill temperature the quantity of water—equaling several times the weight of ore treated and introduced at nearly a freezing temperature—to replace the water and waste solution discharged with the tailing, which would not be necessary if crushing were done in solution. The loss of gold left in 'waste' solution after precipitation must also be added to the cost.

"In comparing Dome and Hollinger metallurgical practice, it is only fair to state that since the Dome ore is harder and more compact, the gold may be less spongy and therefore less amenable to cyanidation. The only deduction which can be drawn from the facts, as far as I know them, is, that apparently in treating average- and low-grade ore of the district amalgamation can be eliminated; that if amalgamation is eliminated and solution introduced at the stamps, a considerable saving in operating cost, cyanide, and dissolved gold losses is possible.

"Unquestionably more extensive study has been given to the treatment of the Dome ore than to any other in the district. Hence one hesitates to make what may appear to be a criticism of an operating system probably justified by a careful balancing of co-ordinate factors by an eminent firm of metallurgists. However, no metallurgical discussion would be complete without touching upon this point, which is the salient difference between the two metallurgical systems of the district."

On the subject of concentration vs. non-concentration, it is Mr. Cunningham's opinion that concentration warrants careful consideration on the score of being able to give a portion of the ore the special treatment it demands instead of subjecting the entire ore to treatment necessary for only a part of it.

For agitation, the author considers the Dorr agitator well adapted to the treatment of the quick-settling and granular slime, particularly on account of being able to give selective agitation to a part of the ore requiring longer treatment. As to filters, pressure filters will be found more satisfactory than vacuum on account of the quick settling nature of the ore, causing difficulty in maintaining a pulp of uniform density and giving rise to uneven and channeled cakes. Continuous decantation is regarded as specially applicable to Porcupine ores, without the use of filters.

Zinc

Concentration at the Timber Butte Mill.—In a paper read before the Montana Society of Engineers, Butte, Mont., Mr. THEODORE SIMONS described the concentration process used at the Timber Butte mill in treating the zinc ores from the Elm Orlu mine. The mill site on the northern slope of Timber Butte affords the following advantages: gravity system of ore flow; extensive area for tailings; good water supply and transportation facilities. The ore contains zinc and lead as sphalerite and galena; copper as bornite, chalcocite, tennite and tetrahedrite; gold and silver free and chemically combined with the base-metal sulphides. The gangue is quartz, barite, fluorite, rhodonite and rhodocrosite. Iron occurs as pyrite. Lead occurs in small quantity only, 0.75 per cent., and consequently a large expense for its recovery is not warranted. Moreover it is intimately associated with zinc and other sulphides so that a separation is difficult. The percentage of iron is 3.29, and of zinc 18.52. In order to make a satisfactory recovery of the lead and iron it is necessary to enrich those products at moderate cost and get something that will stand further refinement. This is accomplished by Wilfley roughing tables. These tables also recover from 25 per cent. to 30 per cent. of the total zinc in the ore at small cost. With the exception of this roughing operation, the only other gravity separation of mineral is performed on James tables that retreat the coarse part of the finished flotation product. Otherwise, all concentration is by flotation. The capacity of the mill is 450 tons of ore per 24 hours. The ratio of concentration for zinc is 3:1, and for lead-copper-iron, 125:1. Extraction averages about 96 per cent. of the zinc and 92.6 per cent. of the silver.

The striking feature in the gravity-concentration section of the mill is the operation of the Wilfley roughing tables, so-called. They are the first concentrating machines encountered in the mill, and take the undersize from impact screens without any previous classification. The tables not only handle an unusual quantity of material, amounting to more than 100 tons per table,

but they make at the very outset a finished coarse-zinc concentrate, containing from 49 to 51 per cent. zinc, and not more than 4 per cent. insoluble. They also send all the fines coming from the mine and those made in the preceding crushing operations to two Akins classifiers to be separated from the tailings, after which they go directly to the Minerals Separations flotation section, where they belong. Thus none of the intermediate machines is encumbered with this troublesome material, and the losses incident to frequent handling of slimes are reduced to a minimum. All this is accomplished by a clever modification and distribution of the riffles by giving the tables a rather steep inclination (8 deg. to 10 deg.) and by adding the proper amount of wash water.

To unlock the finest included grains of sulphides from the adhering gangue, prior to separation, it is necessary to crush the Elm Orlu ore to between 40 and 60-mesh, maximum. It was found that to attempt to extract zinc from material finer than 40-mesh by gravity concentration gave a low grade of concentrates, and would require a costly installation. This led to the adoption of flotation, according to the process of the Minerals Separation Co. The pulp is kept at a uniform density in the proportion of 3 of water to 1 of ore, and is heated to a temperature of 130 deg. F. by the introduction of live steam. From tests it appeared that with the Elm Orlu ore higher temperatures did not produce better results, while temperatures below 125 deg. reduced the efficiency of the plant.

Sulphuric acid is mixed with the pulp at the rate of 7 to 8 lb. to every ton of original ore going through the mill. Oil is added in the proportion of 0.5 of a pound per ton. Oil is introduced in the mixing compartment of the first cell where the pulp is violently churned by the action of the agitator, which at this plant makes 265 r.p.m. and causes the propeller to run at a peripheral speed of about 1500 lin. ft. per minute. The aerated mixture passes through an opening into the flotation compartment, where the froth containing the sulphides of lead, copper, zinc and iron, as well as some of the richer middlings, immediately rises to the surface while the clean gangue and the leaner middlings drop to the bottom.

The flotation compartment has the shape of a spitzkasten, the apex of which is provided with a valve, adjustable by a handwheel. Through this valve the material that has settled to the bottom of the first cell is drawn into the adjoining cell by the pumping action of its propeller. The process is here repeated, and the sulphides which did not float in the first cell are given a chance to do so in the second, and so on. By the time the pulp has reached the seventh cell of the rougher machines the clean sulphides and the richer middlings have all been floated. The remaining middlings in their passage from cell No. 7 to cell No. 11 are separated from the tailings by the successive flotation of the middlings, until in the bottom of the last cell only clean tailings remain, which are taken to a Dorr thickener for extraction of the hot water. This is pumped to a tank to be reused in the flotation machines. The middlings overflowing from the cells Nos. 7 to 11 are reground in the Hardinge mills and returned to the flotation section.

The float concentrates from the first six cells of the rougher machine is a product rich in zinc (about 47.8 per cent.), but due to the presence of middlings still contains about 14 per cent. insoluble. It is therefore sent to the first and fifth cells of a 200-ton Minerals Separation flotation unit containing eight cells. This is known as the "finisher machine," because it makes a finished sulphide concentrate. On passing the pulp through the successive cells of the finisher the sulphides are floated to the surface, while the clean middlings ultimately reach the bottoms of the fourth and eighth cells, whence they go to Hardinge mills, to be reground and returned to the flotation section.

The float concentrates from cells Nos. 1, 2, 3, 5, 6 and 7 of the finisher machine is a finished sulphide product containing, besides the sulphides of lead, copper and iron, 52 per cent. of zinc and 3.5 per cent. insoluble. The fines in this product overflow as fine zinc concentrates from an Esperanza and a Richards classifier through which the product is passed, the coarser portion of which is retreated on James tables. On these tables the lead and iron are separated from the zinc, and the insolubles in the zinc concentrate are reduced to 3.5 per cent.

The overflow from cells Nos. 4 and 8 of the finisher machine, being apt to contain a varying amount of middlings, is returned by air lift to the same machine. The agitating compartments of the flotation cells are lined with cast iron, and the propellers are made of brass. All agitators of a standard machine are driven from one main shaft by gears, which are protected from dust by steel housings. Gears are placed so that propellers in adjoining cells revolve in opposite directions, thus equalizing the strains on the machines and power transmission.

X-Ray Examination of Metals

Use of the Coolidge X-Ray Tube in Metallurgy.—In the General Electric *Review* for February, 1915, Dr. WHEELER P. DAVEY describes the use of the Coolidge tube in observing the defects of cast metal. Copper cast without the addition of boron gives a radiograph showing the pores in the metal, while a radiograph of boronize copper is without spots. The radiograph can be made by a two-minute exposure, the current through the tube being 2.8 milli-amperes and the potential difference across the tube corresponding to a 10-inch parallel spark gap between points. The advantage of the radiograph in experimental work is obvious, as it permits the determination of defects without machining the metal or destroying the casting. It is possible, also, to make stereoscopic radiographs, showing defects in their entirety and estimating their depth. A wide field for further work is opened by this use of the X-ray tube.

Instruments

The Measurement of Rapidly Changing Temperatures is the subject of a discussion by ALFRED PETERSEN (*Zeit.* d. Ver. Duetsch. Ing., April 18, 1914; in abstract in *Bulletin* de la Soc. d'Encouragement, Aug.-Sept.-Oct., 1914, p. 328). To follow instantaneously the changes of temperature, for instance, in the cylinder of an internal-combustion engine, an electrical instrument must be used, either a thermocouple (platinum, platinum-rhodium) or an electric resistance pyrometer (platinum-iridium, containing 35 per cent iridium). For measuring the current an Einthoven string galvanometer is used, for calibration of the thermometers an electric furnace. Some experiments were made under what conditions variations of 1800 deg. C. during one-tenth second could be measured. For this purpose the thermo-element or resistance wire were mounted on a revolving disc, so as to carry them at the proper intervals through a Bunsen flame. Only thermo-couples of 0.02 and 0.03 millimeter or resistor wires of 0.02 millimeter reached the temperature to be determined in this time, and only the resistance pyrometer completely recovered its original temperature at the end of one-tenth of a second.

TABLE I

Experiment No.	5	6	7	Average
Battery	5 Stamps	5 Stamps	5 Stamps	....
Weight of stamps in lb.	1300	1300	1300	1300
Drops per minute	103.5	106	103.3	104.27
Average height of drop	7.8 in.	7 in.	7.5 in.	7.43 in.
Hp. at motor	17.12	16.2	16.92	16.75
Hp.—"Actual" from weight stamps × drops per min.	13.25	12.18	12.72	12.72
Percentage actual of motor hp.	77.3%	75.2%	75.2%	75.9%
Screening used	12 = 8 I.M.M.	30 = 22 I.M.M.	30 = 22 I.M.M.	....
Lb. ore crushed per minute	44.7	33.8	31.04	36.51
Lb. water used per minute	474	472	405	450
Average temp. C. of ore, feed	22.15	24.2	22.0	22.783
Average temp. C. of water, feed	27.07	27.96	26.51	27.180
Average temp. C. of pulp, dis	27.483	28.372	27.00	27.618
Diff. temp. ore, feed and discharge	5.333	4.172	5.00	4.835
Diff. temp. water, feed and discharge	0.413	0.412	0.490	0.438
Heat units from ore, S.H. = 0.251	44.7 × 0.251 × 5.333 = 59.83	33.8 × 0.251 × 4.172 = 35.39	31.04 × 0.251 × 5.00 = 38.95	36.51 × 0.251 × 4.835 = 44.49
Heat units from water, S.H. = 1	474 × 1 × 0.413 = 195.76	472 × 1 × 0.412 = 194.46	405 × 1 × 0.490 = 198.45	450 × 1 × 0.438 = 197.10
Total increase in heat units per minute	255.59	229.85	237.40	241.59
Hp. represented by heat units as $\frac{\text{H.U.} \times 1390}{33{,}000}$	255.59 × 1390 / 33,000 = 10.76 hp.	229.85 × 1390 / 33,000 = 9.68 hp.	237.4 × 1390 / 33,000 = 9.999 hp.	241.59 × 1390 / 33,000 = 10.170
Percentage motor hp. returned as heat	62.84%	59.7%	59.09%	= 60.7%
Percentage actual hp. returned as heat	81.2%	79.5%	78.6%	79.95%
Size of ore before milling	—2 in + ¾ in. ring	—2 in. + ¾ in.	—2 in. + ¾ in.	....
I.M.M. Mesh after milling.. — 8 + 30	% 36.12	%	%	....
— 22 + 30	....	5.09	5.02	....
— 30 + 40	6.61	9.11	9.24	....
— 40 + 60	7.87	12.77	14.32	....
— 60 + 100	2.42	13.15	14.95	....
—100 + 120	5.07	5.08	3.97	....
—120	41.91	54.80	52.59	....

Crushing and Grinding

Heat Developed in Crushing.—An investigation made to determine whether the heat evolved in crushing could possibly indicate the energy used, has been made by Mr. JAMES COOK, and reported in *Bulletin* No. 124, Institution of Mining and Metallurgy. The results are given in the accompanying Table I. The conditions of the experiment were as follows: The weight of the stamps was calculated to be within a few pounds of the round figure used, but no allowance was made for loss of weight during the three-day period of the test. The number of drops per minute was determined frequently. The average height of drop is only approximate, as it could not be determined continuously. The E.H.P. of the battery motor was read continuously and the average taken. The actual horsepower is merely the product of the estimated weight of the stamp, and the number and height of drops. The orifice of the screen used was accurately known, and various meshes were used to see whether the heat evolved varied with the mesh. The weight of water used and ore crushed were found by two methods: (*a*) gaging the water feed and the proportion of solid in the pulp sample; and (*b*) running the entire pulp into a measured tank for a certain time, and ascertaining the amount of water and solid.

The specific heat of the ore was calculated from an analysis of the ore to be 0.251, which was confirmed by a rough test in our laboratory.

The product of the number of pounds of ore crushed per minute, the specific heat, and the rise in temperature in degrees Centigrade, together with the product of the number of pounds of water per minute, its specific heat, and the rise in degrees centigrade gives the total heat units evolved per minute. This multiplied by 1390 —the number of foot pounds in one H.U. centigrade—divided by 33,000 gives the total horsepower per minute represented by this rise in temperature.

For the purposes of my original experiments the pulp was graded through I.M.M. screens as shown in the three examples given.

Of the E. H. P. supplied to the motor, it will be seen that only 76 per cent. is apparently stored in the raised stamp. The ore crushed will be seen to have been raised an average of 4.8 deg. C. while the water used was raised an average of 0.438 C.

The difference is due to the smaller portion of ore feed being at a lower temperature than the water feed.

The average temperature of the ore feed was ascertained at intervals by burying the thermometer in the ore shoot supplying the automatic feeder. This temperature was found to be practically constant.

The average temperature of the water feed was found by frequent tests.

After numerous experiments it was found that the best method of ascertaining the pulp temperature was to take large samples from the entire pulp stream into which the thermometer could be inserted and examined undisturbed.

The temperature of the building was not sufficiently above that of the pulp or feed to affect the temperature during the time of reading. The same thermometer was used to take all temperatures. This, though somewhat inconvenient, avoided any instrumental error.

The thermometer, a very sensitive one, divided into tenths of degrees centigrade, could be estimated easily to further sub-divisions by means of a magnifying glass.

Of the actual power input to the motor, practically 61 per cent. is returned as heat in the pulp. Of the energy which reached and was stored in the lifted stamp, practically 80 per cent. is returned as heat in the pulp. The 20 per cent. unaccounted for may be allocated as follows:

(*a*) Loss in friction with the guides; (*b*) loss in sound and vibration; (*c*) loss in radiated heat; and (*d*) energy with which the pulp is delivered through the screens.

At some points the screen had a higher temperature than the pulp, showing the energetic bombardment to which it was subjected by particles which partly passed or which were returned. From the table it will be observed that a difference of 3 per cent. in the heat energy was found with the two different meshes. The author is inclined to regard this as experimental error. The ore experimented on was a gold-bearing conglomerate.

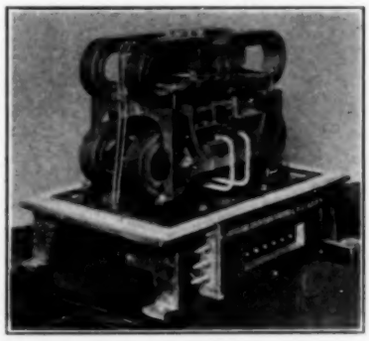
The safety-first publication of the Anaconda Copper Mining Co., known as *The Anode*, has made its appearance. It is designed to promote the safety of Anaconda men in various departments of work. We extend to *The Anode* our best wishes for a useful career.

A New Ampere-Hour Meter for Electrolytic Works and Refineries

In the electrolytic refining of metals, and in all electrolytic processes, the quantity of current used is one of the most important quantities to be measured. If measured in ampere-hours its quantity is directly convertible into pounds of copper or other metal deposited or into pounds of caustic soda and chlorine, obtained in the electrolysis of brine solutions, and affords a direct determination of the current efficiency according to Faraday's law.

It happens that in the development of the latest form of conveyor scales it became necessary to produce an ampere-hour meter of very much greater accuracy and permanence than any that had been constructed in the past and from which all delicate parts were eliminated. This resulted in the meter described below, which is also unique in the absence of any mechanical connection between the integrating element and the registering device.

The meter is of the well known mercury motor type, but the dimensions and weight of the parts have been increased many times over what has been customary in the past. The driving element, or motor chamber, is a shallow reservoir of mercury in which a copper disc revolves. Four heavy double permanent magnets with suitable pole pieces create the driving field. The torque produced is more than seven times as great as has been the usual practice. The shaft of the driving disc is extended upward and carries a large aluminium damping disc. The damping field is produced by four double magnets of the same size as the driving magnets, but with toothed pole pieces to increase the effect of the eddy currents. Above the damping disc on the same shaft is a small copper disc carrying one or more platinum points, which alternately pass just over the rim of two steel cups. Each of these cups is connected with a reservoir of mercury in such a way that a meniscus is produced which is gently swept by the platinum points. In this way a contact is effected which is available for operating the counter without drag upon the rotating shaft. The entire shaft with its driving and damping disc is floated in the mercury of the motor chamber so that there is a very slight upward pressure. The upper end of the shaft is a small polished pivot of hard steel which runs in a cupped diamond end jewel and the lower end of the shaft is simply held in place by a polished sapphire ring jewel. No oil of any kind is used on the jewels.



AMPERE-HOUR METER

The result is a meter with only one moving part the motion of which is entirely controlled by magnetic and electric forces. Not only is the driving force greatly increased, but mechanical friction is reduced to the vanishing point. This gives a speed to the meter shaft which is dependent only on the volume of current and which cannot change with the lapse of time on account of the absence of friction and mechanical wear, as well as the absence of lubrication, the condition of which would vary.

Passing now to the registering part, this is simply an electric counter of new design which constitutes a rather radical departure. There is a rocker shaft actuated by two electric counters. This rocker shaft is the only moving part except the six number wheels. There are no springs or ratchets. The rocker shaft carries a hermetically sealed glass tube containing a small quantity of mercury which oscillates with the motion of the counter, and makes and breaks a contact connected with binding posts on the outside of the meter. This auxiliary circuit is available for the connection of distant registers or recording instruments. When a recording counter is used the meter gives a graphic record of the operation of the plant for every hour of the day. In this way all shutdowns, even if of a few moments' duration, are plainly indicated, and the quantity of current delivered during any hour or any fifteen minutes of the day or night is plainly read.

The meter is equipped with suitable shunts making it available for any volume of current that is to be measured. It is manufactured by the Electric Weighing Company, 180 Thirteenth Avenue, New York City.

The Analoid Method for the Determination of Phosphorus in Steel, Iron and Slag

The standardization of analytical routine methods in iron and steel laboratories is making further progress, as is instanced by the success and further development of the "analoid method" of analysis. Invented by the English steel chemists, Messrs. C. H. & N. D. Ridsdale, and introduced in this country by the Scientific Materials Company of Pittsburgh, this method depends on the use of "analoids," that is, tablets containing just the exact quantities of the proper reagents, which have been carefully tested and apportioned to give the best result for a certain reaction in the method for which they have been specially prepared.

In our issue of December, 1914, we described the analoid method for the determination of manganese in steel, iron ore, and slag. The analoid method of determining phosphorus is perhaps of still greater value for the routine laboratory and will be described in the following article:

Preparation of Sample.—Metallic samples consisting of moderately fine drillings are suitable; however, with 0.6 to 0.8 carbon steels or higher the samples should be very fine to facilitate solution. Cast iron, should, if drilled, consist of very fine drillings, preferably pounded afterwards, or if shot samples, should be pounded to pass a 60-mesh sieve. Slags, etc., should have the same fineness.

Preparation of Solutions.—Reagent No. 1.—Nitric acid. Mix 21.5 parts nitric acid, 1.42 sp. gr., with 10 parts by volume of 3 per cent (at least) hydrogen peroxide.

Reagent No. 2.—Ammonium molybdate. Add 300 cc. of distilled water to 74 grams of molybdic acid (MoO_3) and mix well, add slowly 60 cc ammonium hydrate, 0.90 sp. gr. (or more, if not neutral to litmus), warm to not over 50° C. to aid in solution, filter and dilute to 1 liter with cold water.[1]

Reagent No. 3.—One-sixth normal sodium hydroxide (6.667 grams per liter). This solution can be prepared free from carbonate by making a saturated solution of NaOH (by alc.) in about 50 cc of distilled water. Enough NaOH must be used so that some remains undissolved together with any sodium carbonate. Allow to settle and decant clear solution into a bottle which

[1] The operator should be cautioned not to use an acid solution of molybdate, as it alters the proportioning of the reagents, volumes of liquid, temperature of precipitation, and gives erroneous results, unless proper allowance is made.

must be kept stoppered. Use 6 to 7 cc of this solution per liter of distilled water. Standardize against steel of known phosphorus content.

Reagent No. 4.—Nitric acid. Make a nitric acid solution exactly equivalent to the above sodium hydroxide solution which will be approximately correct by diluting 20 cc nitric acid, 1.42 sp. gr., to 2 liters.[2]

Procedure for Steels up to 0.3% Phosphorus.—Place the 2-gram sample in a 300-cc Erlenmeyer flask which has an approximate graduation mark at 55 cc, and add 55 cc of reagent No. 1 (nitric acid). After vigorous action has subsided, cover with small watch glass and heat at just below the boiling point until solution is complete and the brown fumes practically expelled.

Add one No. 4 analoid and heat gently for two minutes to destroy all soluble carbonaceous matter and insure complete oxidation.

Then add one No. 5 analoid, bring quickly to boil till clear, then hold at just below boiling for at least two minutes. Rinse cover of flask and dilute to 55 cc (if volume is less) with boiling water. Now precipitate the phosphorus at a temperature of 72-78° C. by adding to the boiling solution 20-25 cc of cold (10°-19° C.) neutral ammonium molybdate solution No. 2 giving a total volume of 75 to 80 cc. Shake well (vertical motion) for full two minutes and allow to settle (stoppered) for about two minutes at about 40° C. If phosphorus is low shake 5 minutes and allow to settle 10-15 minutes.[3]

A yellow precipitate, both chemically and physically perfectly uniform, granular to facilitate filtering and washing, is produced. These qualities render it especially suited to centrifugal machine treatment to produce reliable results. The precipitates so obtained may be filtered and finished by any of the customary methods, but the following method is recommended.

Filter through good quality analytical filter paper using suction, rinsing the flask with 2 per cent nitric acid, and washing till free from acid, with a solution made by dissolving one analoid No. 14 in 30 to 40 cc of hot water, cool and dilute with distilled water to one litre.[4]

The paper is removed from the funnel placed open against the inside of a 250 cc beaker, and the necessary amount of 1/6 normal sodium hydroxide solution (20-25 cc) allowed to wash the precipitate into the beaker, using an accurately graduated pipette or burette. The liquid is stirred with a glass rod until dissolved, the filter paper broken up in the solution, 100-150 cc of cold distilled water added, also 1-2 drops of phenolphtalein solution (1-100 alcohol) and the excess of sodium hydroxide titrated back with the equivalent nitric acid solution.

The difference from total NaOH used gives the number of cc. reacting with the ammonium phosphomolybdate. This multiplied by the phosphorus factor gives percentage of phosphorus (or weight if so calculated).

Procedure for Cast Iron and Pig Iron.—Sample 2.857 grams (for percentage up to 0.3 phosphorus) placed in a 250 cc beaker and dissolved in 75 cc of nitric acid solution No. 1, covered and heated gently until brown fumes are expelled. Transfer to a 100 cc flask, dilute to exactly 100 cc with cold water, shake and filter through dry filter into a dry beaker. Exactly 75 cc are transferred to a 300 cc erlenmeyer flask graduated at 75 cc. (This gives a sample equivalent to 2 grams of iron). Cover flask and heat just to the boiling point and add one analoid No. 4, simmer at least two minutes and add one analoid No. 5, heat quickly to boil until clear, then simmer at least 2 minutes. Dilute to 75 cc with boiling water and precipitate at a temperature of 68-72° C. by adding to the boiling solutions 25 cc of cold (10°-19°) neutral solution of ammonium molybdate No. 2 diluted to 40 cc with cold water, shake 5 minutes, then allow to stand as directed in procedure for steels.

The method with slight modification is adapted for analysis of high-phosphorus irons (up to 3 per cent), also to high-phosphorus slags and fertilizers.

We have described in detail the analoid method for phosphorus determination, in order to bring out in which regards it means a considerable simplification of usual methods. This matter is gone into with greater detail in a pamphlet just issued by the Scientific Materials Company of Pittsburgh, Pa.

[2] Although solutions No. 3 and No. 4 are for use in the "acid-alkali" method, any of the usual methods may be used after the precipitation of the yellow precipitate.

[3] If the solution is allowed to stand in a warm place much longer than the prescribed time, arseno and silico molybdates may be more or less precipitated and give a high result; but if at ordinary temperature, 18-23° C., this is usually avoided.

[4] This removes the acidity without dissolving the yellow precipitate whereas water if used would dissolve it.

Sentinel "Pyrometers" and Paste and Their Uses

A new method for measuring temperatures, similar in principle to Seger cones, has been developed by the Carl Nehls Alloy Company, of Detroit, Mich. Different kinds of metallic salts have been made up of such chemical compositions as to have definite different melting points throughout the temperature range between 425

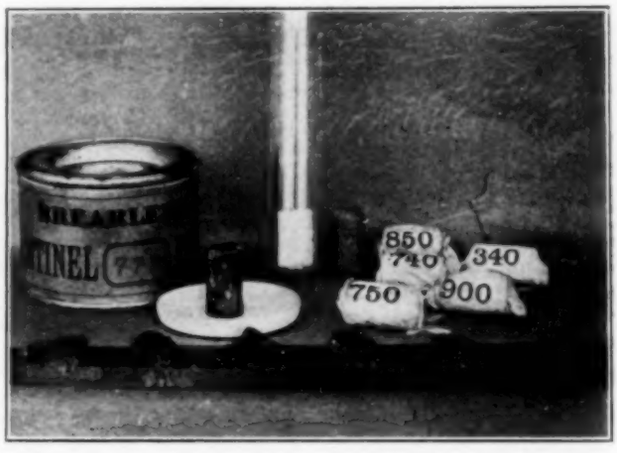


FIG. 1—SENTINEL PYROMETERS AND PASTE AS MADE AND USED

and 2425 deg. Fahr. (218 to 1329 deg. Cent.). They may be used, like Seger cones, for measuring temperatures, and are also very useful for checking pyrometers. For the latter purpose a cylinder is placed at the end of the thermocouple and when it melts the pyrometer should read the same as the temperature marked on the "Sentinel."

One way of using these metallic salts compositions is to cast them into solid cylinders, 7/16 in. in diameter and 3/14 in. long, as shown by those standing on one end in Fig. 1. Each one is wrapped in a paper on which is printed its correct melting temperature in degrees Centigrade. These are shown by the samples lying down. For all temperatures below 932 deg. Fahr. these "sentinel pyrometers" can be used in an air-tight glass tube such as is shown in the center. The salts can then be used over and over again. By using the small porcelain saucer shown, the salts do not run to waste and litter up the place where they are used. This also enables them to be used several times, as the salt will melt each time the temperature raises above the one marked on the cylinder and it will become solid again the moment the temperature falls below this degree.

These salts are also made up in the form of a paste.

Enough to make several hundred determinations is packed in the tins shown. Pastes with various melting temperatures can be daubed along a steel bar, as shown in the front of Fig. 1, and inserted into ovens, furnaces, retorts, flues, gas mains, steam pipes, etc., to find the temperature at which they are operating. The salts that melt down and those that remain solid will indicate the temperature which would be between the two. By using a long bar one can determine whether the temperature is uniform in the front and back, top and bottom, or corners of a furnace, oven, kiln, etc.

This is an easy method for obtaining the exact temperature of tools heated in a forge fire. A paste is

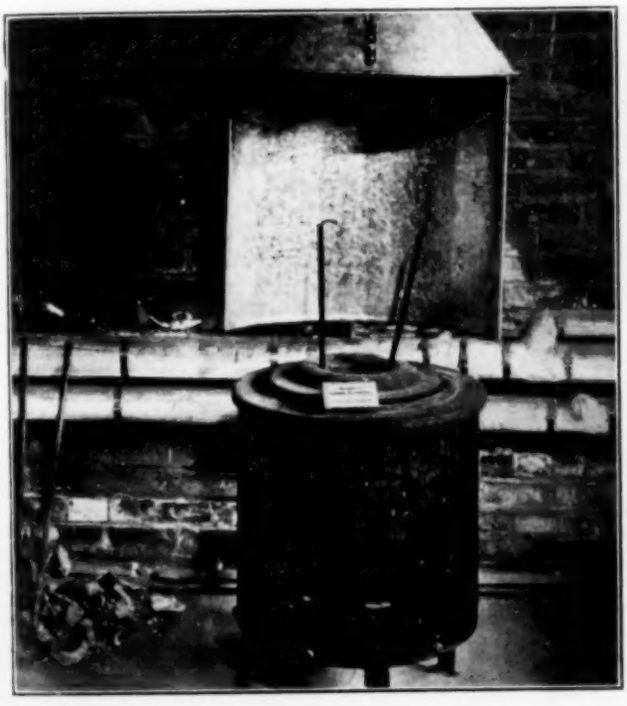


FIG. 2—"SENTINEL PYROMETER" USED IN TUBE IN POT FURNACE

selected that represents the correct hardening temperature for the tool. This "sentinel paste" is daubed on the tool and when it is heated to this temperature the salt will melt and the tool can be taken out of the fire and quenched. It will make it easier if the tool is surrounded by a piece of sheet steel or is inserted in gas pipe as that keeps the paste from coming in contact with the fuel.

Another handy way of using the "sentinel" cylinders is to plug one end of a tube or pipe and drop a sentinel cylinder into the tube. A small rod can then be lowered into the tube and made to rest on the salt. When the salt melts down the rod will lower and thus indicate that the melting temperature of the salt has been reached. This is very useful for finding the temperature of molten metal, salt bath furnaces, etc. Fig. 2 illustrates this method.

A Special Paper for Recording Instruments, Drawings and Similar Purposes

A chemically surfaced paper of high merit has recently been put on the market by the Non-Carbon Paper Company, 14 Federal Street, Boston, Mass., which should be of considerable interest to manufacturers and users of recording and registering instruments. Several years of experimenting and a large expenditure have been necessary to produce a product of this kind.

To produce a paper which would be satisfactory as a chart for the various kinds of instruments, some requiring a sensitive surface and some a hard one, was the problem to be solved. Further, a surface had to be created upon which printing could be done satisfactorily for the making of charts, graphs, tapes and other devices. Then the sensitiveness had to be satisfactory within the wide range from the recording instruments requiring a firm surface to the more sensitive finish required by instruments of a delicate nature. These problems have all been worked out and a high-grade paper manufactured to fit any and all of these needs.

Another valuable feature of this paper is its utility in the engineering department for the production of sketches and drawings. A still wider field is opened up by the fact that this paper is especially valuable in the second-sheet field, where records of correspondence may be made through its use without the aid of carbon paper. This paper is adaptable to auto trucks and vehicle recorders, speedometers, electric and water meters, steam gauges and water-pressure instruments, recording thermometers, pyrometers, hightenographs, magnetographs, time locks and time registers, movement indicators, fatigue testing instruments, pulsation recording and respiration registering devices, pneumatic orbits or movements of scientific machines. Copies of records can be obtained by inserting sheets corresponding with the form print.

Bronze Castings as a Substitute for Steel Parts

Machine parts of steel are inexpensive as far as the cost of the material is concerned, but if the cost of machining, grinding, hardening, finishing, etc., is considered, they may become so expensive that their equal weight in bronze or silver, or even gold, will be worth less. Often a preferable machine construction has to be abandoned for the reason that the making of one or more of the necessary parts cost too much if same have to be machined, especially in quantity work.

Where strength, toughness, resilience, wearing quality and durability could be neglected, the products of the white-metal die-casting industry overcame the obstacle caused by the high machining cost, as its products leave the moulds smooth, true and accurate, and therefore need little finishing work. However, the good qualities of steel, either soft or hard, can be reached and even greatly excelled by brass (copper with zinc), bronze (copper with tin) and other modern copper-base metal compositions, but against their use stands their high material cost unless the same can be balanced by the saving of finishing labor, as is often the case.

If, however, it becomes possible to produce also copper-base metal composition die castings smooth and accurate, then the saving of finishing expenses in many instances would excel the higher cost of the material, and at the same time there would be an opportunity of substituting a superior material for the steel.

The McGill Metal Company of Valparaiso, Indiana, has entered this new field of industry, that is, of casting copper-base metal compositions in permanent steel moulds or dies. After systematic experimental work and after furnishing bronze-die castings for two years to a limited number of customers for thorough tests, this company saw such an encouraging success that it is now erecting a new permanent foundry and die shop with a modern equipment for making bronze castings in permanent steel moulds.

Among the many difficulties which the experimental plant had to overcome were: To work out bronze compositions of perfect equilibrium at all temperatures,

and of sufficient strength, even at a high temperature to withstand all strains caused by its own shrinkage around the steel cores in the dies. Even the best brasses and bronzes used commercially heretofore fell short in these requirements, likewise no make of steel found on the market did meet the requirement of withstanding the attack of molten metals at temperatures of from 2200 to 2400 deg. F., as is needed with the mould material. Therefore, special steel alloys had to be developed to suit the purpose.

One of the fields in which the McGill metal castings worked remarkably successful was the quantity production, at a reasonable price, of strong, tough, hard and durable bevel-gears with correct teeth. As is well known, the cost of cutting correct bevel gear teeth is prohibitive in regular quantity manufactured, however, if the cutting of correct teeth need to be done for once only in a die, and if in this die hard and tough bronze can be cast successfully the production of strong and correct bevel-gears can be accomplished without needing any mechanical work at all on the teeth. And if the material is superior to correctly case-hardened or tempered steel in every respect, then also the manufacturer avoids the uncertainty and risks of the heat treatment of steel. These aims are accomplished by the McGill metal casting process.

The McGill metal castings are finely granular or fibrous and homogeneous, have a great cohesion and flowing power even with their hard varieties; they can be forged red hot or cold, and can be machined with ease. Vibrations, shocks, strains as well as heat if within reasonable limits will not influence their fine and uniform grain, nor their strength, hardness, toughness and springiness as continuous exposures for two years have proven. Those qualities can be regulated by varying the compositions. Not being attained by secondary treatments these qualities being innate will last and not change in time or by use.

The castings take a high polish on account of the fine close grain, and will practically show almost no wear even when run without lubricator, under great load, and with great speed. Therefore, they are ideal where subject to rolling, sliding or pounding, as is the case with gears, cams, clutches, couplings, sliding (reciprocating or rotating) valves, poppet valves, bearings and bushings.

The color of the metal is a golden yellow. It contains about 90 per cent copper and withstands well the action of acids, alkalies and salts. The users of the material will not be troubled with rusting and corroding, nor with pitting. Against the latter the hardness and closeness of its grain is an additional protection.

Physical tests with the material gave the following results: Tensile strength, 75,000 to 85,000 lb. per square inch, with an elastic limit of 30,000 to 40,000 lb., and elongation of 18 to 23 per cent on a 2-in. test length, and a reduction of area of 17 to 24 per cent.

Portable Welding Outfit for Metallurgical Works

The rapid progress made by autogenous or fusion welding throughout the metal industry is an indication of the numerous advantages possessed by the process. The object of this method of welding is to bring the metal, at the point of treatment, to a liquid state so that the parts to be united will fuse and flow together in a practically homogeneous piece. The heat employed for the purpose may be generated either by electricity or by means of thermit or by burning a combustible gas with oxygen.

Acetylene gas is highly suitable for the purpose, the temperature of the oxy-acetylene flame being about 6300 deg. Fahr. The decomposition of acetylene (C_2H_2) when burned with oxygen presents some features valuable in welding. The high temperature of the oxy-acetylene flame, caused by the combustion of carbon, is above the temperature of dissociation of steam, so that water is not formed as a product in the flame. The hydrogen from the acetylene does not enter into combination with oxygen until after it has left the high-temperature zone of the welding flame. This produces a zone of hydrogen, more or less free, surrounding the welding flame, giving a reducing atmosphere and preventing oxidation of the metal.

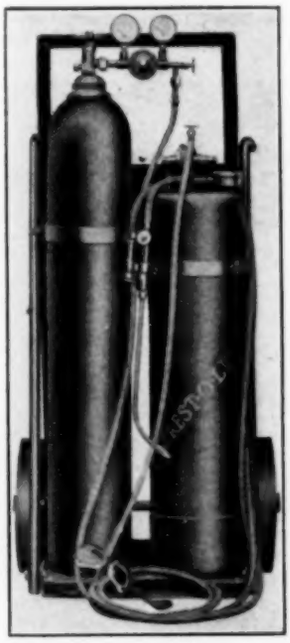


FIG. 1—PORTABLE WELDING OUTFIT

The application of oxy-acetylene welding is a comparatively simple matter in ordinary work, and men are readily trained to use it efficiently. The process, therefore, is one that can be profitably applied in repairing broken machinery in concentrating and cyanide mills, smelters and metallurgical works generally. At isolated plants it is especially valuable in reducing losses incident to broken machines, and avoiding delays due to getting new parts or sending broken ones out for repair.

The process has been made particularly available for this kind of work through the portable Prest-O-Welder outfit, which has been placed on the market by the Prest-O-Lite Company, Inc., of Indianapolis, Ind. As shown in Fig. 1, it consists of two cylinders, with pressure gages, hose, blow-pipe and tips, mounted on a truck. One of the tanks contains compressed oxygen and the other acetylene prepared according to the Prest-O-Lite process. The oxygen cylinder can be recharged at various places in the country, and the Prest-O-Lite cylinder is exchangeable through the company's numerous service stations which are widely distributed.

The entire outfit weighs less than 300 lb., and being portable and compact, it affords the greatest convenience and efficiency. In this respect it is superior to stationary acetylene generating apparatus, to which repair work must be taken, often at added expense or inconvenience. The purity of Prest-O-Lite gas is an added advantage over that generated from carbide and water, for the impurities in the latter affect the weld and can be removed only through the use of expensive apparatus. Further, Prest-O-Lite will not freeze in cold weather and is always ready for use. The entire apparatus is simple, durable, convenient, safe and under perfect control. Considering these features, it should find a broad field of usefulness in mills and smelters.

The Iron and Steel Market

Steel mills at the end of February were operating at between 55 and 60 per cent of capacity. Operations in January averaged fully 45 per cent of capacity and the average for the first two months of the year is fully 50 per cent, against about 35 per cent in November and December.

The recovery in demand is real, but it is halting and

hesitating. The mills have maintained their increased rate of operation only by making up their rolling schedules at short intervals, practically from day to day, and any decrease in the current demand would at once be followed by decreased operations.

There has been little if any increase in the demand for steel for important permanent investment. The railroads have taken a very small part in the buying, and there is very little in the way of large structural enterprises. It would appear that what has occurred is simply that towards the close of the old year jobbers and manufacturing consumers drew upon stocks, causing mill production and shipments to fall below the actual rate of ultimate consumption, and that since the first of the year this factor has disappeared, while there has been a slight increase in consumption.

The hopes of the steel trade now rest upon an increase in consumption due to the near approach of spring, permitting an expansion in outdoor work and due also to the better financial and economic conditions which should lead to the investment of capital in extensions and new enterprises.

Export trade holds out no great hopes, as there were declines in November and December from the record of October. Exports of iron and steel, including scrap, pig iron, rolled iron and steel, cast and wrought pipe, wire, nails, etc., have been as follows, in gross tons:

January	118,770	July	114,790
February	121,206	August	86,599
March	159,998	September	96,476
April	161,952	October	147,293
May	139,107	November	140,731
June	144,003	December	117,655

Year—1,548,680

For about a year and a half the steel industry has been operating at all times at considerably less than its capacity and while statements are made in the trade with more or less confidence that this or that plant, or the industry as a whole, is operating at a certain percentage of capacity, it is doubtful whether the real capacity is definitely known. It is possible that under the most favorable circumstances an output could be attained much beyond the rated capacity, and it is equally possible that upon short notice the industry could not reach a rate of operating even at nominal capacity, there being in the chain so many links of uncertain strength. It might be therefore that with a further and only moderate increase in demand the mills would begin falling behind in deliveries of some products. Such an event would undoubtedly arouse overnight a demand for hundreds of thousands of tons of steel, as jobbers and manufacturing consumers are operating with extremely light stocks, being able as a rule to secure shipment from mill a few days after the filing of specifications, and any question raised as to the promptness of shipment would at once induce these buyers to attempt to add to their stocks. Despite the very conservative views entertained on all hands as to the future of the market in the next few months there is a distinct possibility of a period of decided activity marketwise with consequent sharply rising prices.

Pig Iron

The pig-iron markets throughout the country have been showing remarkable steadiness in prices and a very decided lack of activity at the same time. The buying movement of late in the old year seems to have covered consumers comfortably, as to their present rate of operation, as there are practically no complaints of consumers not taking deliveries as contracted for, yet the total production continues light, as light as for several years. There has been a sharp increase in pig-iron production by the steel interests, but none by the merchant furnaces. As many of the existing contracts are for the quarter only, an increase in buying is expected in March. Quotations show scarcely any change from those of one month or two months ago, and are as follows: No. 2 foundry, Birmingham, $9.50; delivered Philadelphia, $14.50; f.o.b. furnace, Buffalo, $13; delivered Cleveland, $13.25; f.o.b. furnace, Chicago, $13; at valley furnaces (95 cents higher delivered Pittsburgh) Bessemer, $13.60; basic, $12.50; No. 2 foundry, $12.75 to $13.25; malleable, $12.75; gray forge, $12.50 to $12.75. Ferromanganese on contracts is nominal at $68, Baltimore, there being question about delivery on account of the embargo. Small prompt lots have been commanding $85 to $100, a decided advance in the month.

Steel

It develops that one or two of the Youngstown mills did not secure as much billet and sheet bar business as desired, and they have not participated in the advances made by Pittsburgh mills, the result being that quotations at Youngstown are substantially as low as a couple of months ago, while the Pittsburgh mills are forced to be content with their contract tonnage and are not naming competitive prices. We quote billets at $18.25 to $18.50 and sheet bars at $18.50 to $19, f.o.b. maker's mill, Youngstown, and $1 higher delivered Pittsburgh. Rods are $25 to $26, Pittsburgh.

Finished Steel

In December the regular market for bars, plates and shapes was 1.05c. for specifications to be filled in December for early shipment, 1.10c. for first quarter contracts and 1.15c. for second quarter. At the end of December the 1.05c. price was withdrawn. Early in February former prices for forward deliveries were withdrawn, mills then quoting 1.10c. for February specification, 1.15c. for March and 1.20c. for second quarter, in substance leaving it to the calendar to effect an advance, and the question is whether the beginning of March will witness a disappearance of the 1.10c. price. At the same time the National Tube Company began quoting steel pipe at a one-point advance for specifications to be filed in April, and a two-point advance for May and June. This was followed on February 11 by the issuance of a new list with a straight advance of one point on black steel pipe 6-inch and under, and an advance of three points on galvanized steel pipe ¾ to 6-inch, this extra advance on galvanized pipe being due to the record high price and extreme scarcity of spelter. Effective February 12 wire products were advanced $1 a ton. The continued advances in spelter forced higher and higher prices for galvanized sheets and in the last week in February all the mills that were quoting at all advanced to 3.40c. for 28 gage, even then accepting orders only for immediate specification and prompt shipment. Nominally the advance due to the advance of spelter to nine cents or higher is $13 a net ton, but practically it is $16, as while the openly quoted market had not gone below 2.75c. there were some contracts made in December at 2.60c.

Current quotations are as follows for ordinary deliveries, quotations being f.o.b. Pittsburgh unless otherwise noted.

Rails, standard sections, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.10 to 1.15c.

Shapes, 1.10 to 1.15c.

Steel bars and bands, 1.10 to 1.15c.; base, hoops, 1.25 to 1.30c.

Refined iron bars, 1.15c., Pittsburgh; common iron bars, 1.12½c., Philadlphia; 1.05c., Chicago.

Sheets, blue annealed, 10 gage, 1.30c.; black, 28 gage, 1.80 to 1.90c.; galvanized, 28 gage, 3.40c.; painted cor-

rugated, 28 gage, 2.00c.; galvanized corrugated, 28 gage, 3.45c.

Tin plate, nominal price $3.20 for 100-pound cokes; large lots at $3.10 or possibly less.

Steel pipe, ¾ to 3-in., 80 per cent off list.

Steel boiler tubes, 3 1/3 to 4½-in., 74 per cent off list.

Standard railroad spikes, 1.35c., Pittsburgh; 1.45c., Chicago.

Cold rolled shafting, 68 per cent off list.

Structural rivets, 1.35c.; boiler rivets, 1.45c.

Chain, ⅜-in. proof coil, 3.00c.

Montana Section of American Institute of Mining Engineers

The annual meeting of the Montana Section of the American Institute of Mining Engineers was held in Butte on the evening of Feb. 5. More than fifty members and guests enjoyed a dinner at the Silver Bow Club preceding the business and technical session. The following officers were elected for the ensuing year:

Chairman, F. M. Smith, manager East Helena plant of the American Smelting & Refining Company.

Vice-chairman, J. L. Bruce, manager of the Butte & Superior Copper Company.

Secretary-treasurer, D. C. Bard, professor of geology, Montana State School of Mines.

Executive committee, Frederick Laist, chief metallurgist Anaconda Copper Mining Company, and W. C. Siderfin, manager of the W. A. Clark interests in Montana.

The secretary's report shows an active membership in the state of 160. Arrangements were considered for having the Montana Section represented at the San Francisco meeting of the Institute next September.

Two technical papers were presented and discussed. One on the concentractor of the Timber Butte Milling Company, by Theodore Simons, (see Synopsis in this issue), the other on "The Boulder Batholith of Montana," by Paul Billingsley. The Montana Section of the Institute meets twice a year. It is growing in membership, and its usefulness is being increased as interest in the organization grows among mining men.

Personal

Dr. Lucien I. Blake, of Boston, is expected in Denver March 1. While there he will deliver a series of ten lectures on Cosmic Physics before the Teknik Club, and an additional course on Molecular Physics at the Colorado School of Mines.

The Colorado Iron Works Company has opened a down-town office in Denver for the accommodation of its friends and customers who may find it inconvenient to visit the main office at the works. The new office in the Ideal Building, Seventeenth and Champa Streets, is in charge of Mr. Hugh B. Lowden, secretary of the company. Mr. Randall P. Akins, sales manager, will also make this office his headquarters when in the city.

Mr. C. A. Filteau has sailed from New York, via Panama, for Carabaya, Puno, Peru, where he will manage the affairs of the Inca Mining & Development Co.

Mr. Robert A. Marr is metallurgist for the Platinum Mining & Milling Co., at Holmes, Wyo.

Mr. **Arthur G. McKee** announces that Mr. **Robert E. Baker** and Mr. **Donald D. Herr**, his business associates during a number of years past, have joined him in the incorporation of the engineering and contracting firm of Arthur G. McKee & Co.

Mr. **Philip S. Morse**, who has been manager of the mines, mills and smelting works of the Sulphide Corporation in New South Wales, has resigned his position and returned to the United States.

Messrs. Jacques Negru, Paul S. Nice and **Thomas Charlton,** all of Denver, Colo., have associated themselves as the Chemical and Engineering Institute. A general consulting business in chemical engineering will be conducted with offices in the Central Savings Bank Building.

Mr. Edgar L. Newhouse has been chosen first vice-president of the American Smelting & Refining Co., succeeding the late Barton Sewell. Messrs. Edward Brush and S. W. Eccles also have been advanced in the line of vice-presidents.

Prof. **Robert H. Richards** has been awarded the gold medal of the Mining and Metallurgical Society of America, in recognition of his services in the advancement of the art of ore dressing. The formal presentation will not take place until March.

Mr. W. G. Swart, mining and metallurgical engineer of Denver, Colo., with offices at the Foster Building, has joined the Hardinge Conical Mill Company in the capacity of consulting engineer in the West.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903.

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Electroplating Alloys

98,110, Dec. 21, 1869, Samuel Rust, Jr., of Cincinnati, Ohio.

Relates to electrodepositing brass and other alloys upon iron, zinc and other metals, and an apparatus therefore, which consists of a large tank having a steam-coil on the bottom. The solution is made as follows: First solution, 1¼ lb. of cyanide of potassium, 1⅜ lb. of carbonate of ammonia, 1 gal. of distilled water; second solution, ½ ounce of bisulphide of carbon, 4 ounces of cyanide of potassium, 1 pint of distilled water, shake until dissolved. To 1 gal. of the first solution add ½ ounce of the second solution, mix and allow to stand for twenty-four hours, or longer. Before using decant as much as possible of the clear solution and filter the remainder from any sediment. Fill the tank and a porous cup with the clear solution, in the porous cup place a brass or copper cathode, and a sheet of brass for an anode in the outer tank; pass a current until the required amount of brass has been dissolved, then remove the porous cup and cathode. The solution is now ready for use. The temperature should be about 180 deg. Fahr.

103,947, June 7, 1870, William Henry Walenn, of London, England.

Relates to electrodepositing brass and describes several electrolytes, one of which is as follows: One part by weight of crystallized sulphate of zinc, two parts by weight of crystallized sulphate of copper, are dissolved in the least possible water. Sufficient strong ammonia water is added to precipitate and then fully redissolve the oxides. The purple tint of this solution is completely removed by a standard solution of cyanide of potassium, left to stand for a day or two, and may then be worked with from one to three battery cells, using heat if a brass anode be employed. The patent should be consulted for further details.

155,700, Oct. 6, 1874, Edmond Boy, of New York, N. Y.

Relates to preparing an electrolyte for depositing an alloy to be used for ornamenting articles of copper, iron, etc. The solution is prepared as follows: To about 200 parts by weight of hot water add twenty parts of powdered arsenic, (probably uses one of the oxides of arsenic); after solution, add twenty parts of cyanide of

potassium, and allow the liquid to remain until it is clear. Grind together one part of sulphate of copper, one part of sulphate of zinc and four parts of carbonate of soda, dissolve in water and mix with the above solution, stir thoroughly and allow to stand. A small quantity of cyanide of potassium may be required to perfect the solution. For use the solution is kept at a boiling heat, the article to be plated suspended therein as cathode and platinum or other metal used as anode. A strong current is required. The deposit obtained is of a lustrous bronze color and highly ornamental.

223,210, Dec. 30, 1879, William Frishmuth and Herman B. Van Tronk, of Philadelphia, Pa.

Relates to electrodepositing an alloy of nickel and aluminium, from an electrolyte containing 6 ounces of nickel chloride, 2 ounces of a mixture made of two parts of chloride of aluminium to one part of chloride of sodium, the proportion of nickel salt and mixed aluminium-sodium salts being dissolved in 1 gal. of water. A strong current is passed through the solution from a nickel anode to a carbon cathode, until the solution is in proper condition for plating, when the carbon is removed. The solution is now ready for use. In place of nickel chloride there may be used nickel sulphate or nickel nitrate.

228,900, June 15, 1880, James S. Howard, of Springfield, Mass., assignor to James M. Abbott, of Waterbury, Conn.

Relates to an improvement in solutions for electroplating with an alloy of which aluminium is the base. One pound of a mixture of one part cryolite, one part chloride of magnesium and one part chloride of manganese, combined in the form of a powder is added to 1 gal. of water and boiled until thoroughly dissolved. The granulated alloy anode is placed either in an open network or may be placed on the bottom of the lead-lined tank, in which latter case the current is connected to the lead lining.

231,064, Aug. 10, 1880, George Linsenmayer, of Philadelphia, Pa.

Relates to electrodepositing an alloy of aluminium and gold from a solution prepared as follows: First solution: To 10 liters of distilled water add 7 ounces of phosphate of soda, 1½ ounce of sal-ammoniac and 1 ounce of magnesia. Second solution: To 5 liters of distilled water, add 2 ounces of bicarbonate of soda, ½ ounce of muriate of soda, ½ ounce of flowers of sulphur and 1 dwt. of acetic acid. Third solution: To 8 liters of distilled water, add 10 ounces of cyanide of potassium and 15 dwt. of spirits of wine. When all the substances are dissolved pour the three solutions together and boil for half an hour, cool and add 2 ounces of burnt alum dissolved in 1 liter of water, 1 ounce of aluminium and 1 ounce of gold, the latter previously dissolved in nitro-muriatic acid and 4 ounces of cyanide of potassium with 1 ounce of aqua-ammonia. Boil again for half an hour, then filter while hot. The solution is now ready for use; it should be used at a temperature of 180 deg. Fahr. to 200 deg. Fahr.

248,554, Oct. 18, 1881, Milton H. Campbell, of New York, N. Y., assignor to himself and Norvin Greene, of same place.

Relates to electroplating silver or silver-plated ware for the purpose of protecting their surfaces from corrosion or tarnishing. The articles are plated with a homogeneous alloy consisting of from twenty-five to thirty-six parts of platinum and seventy-five to sixty-four parts of silver. With less than ten parts of platinum the alloy is not capable of resisting the stronger corrosive agents, such as nitric acid and the sulphides. In making the plating solution, the alloy is converted into a compound chloride of platinum and silver, by dissolving in nitric or nitro-muriatic acid, heated to boiling. This solution is diluted with about four times its volume of water and then a hot saturated solution of chloride of ammonia is added to precipitate the chlorides. About 1 ounce of the compound chloride is dissolved in 1 gal. of water, with a sufficient quantity of cyanide of potassium added thereto to afford a clear solution, which is used as the electrolyte. In electroplating, an anode of the alloy of platinum and silver is used. (See also his later patent No. 253,159.)

253,159, Jan. 31, 1882, Milton H. Campbell, of New York, N. Y., assignor of one-half to Norvin Greene, of same place.

Relates to electroplating silver or silver-plated ware for the purpose of protecting their surfaces from tarnishing while in the wholesale and retail stock and contains a reference to his earlier patent, No. 248,554. The deposit of alloy of platinum and silver described therein should weigh about 6 grains per square foot of electroplated surface. Such a thin deposit will not withstand wear; a heavy deposit is recommended for permanent protection. The current used to effect the deposit should not be too strong or silver will deposit almost exclusively. A current that will deposit 6 grains of alloy per square foot in five minutes is considered about right, although a still feebler current is preferred.

Book Reviews

The Fixation of Atmospheric Nitrogen. By **Joseph Knox.** 5 by 7½ in., 112 pages; price, $0.75. New York: D. Van Nostrand Company.

The author is lecturer on inorganic chemistry in the University of Aberdeen. The theoretical principles are clearly explained, while the technical side is briefly sketched, being principally condensed from T. E. Norton's "Utilization of Atmospheric Nitrogen"—with acknowledgment. Those unacquainted with the subject will find it a good book to begin with.

Cyanamid. Its Manufacture, Chemistry and Uses. By **Edward J. Pranke,** B.Sc. Octavo (14 x 22 cm.), 112 pages; price $1.25. Chemical Publishing Company, Easton, Pa. Williams & Norgate, London.

The topics treated are: discovery and manufacture, properties, analysis, storage, fire and water hazard, decomposition in the soil, toxicity, fertilizing properties. The book is clearly and carefully written, and will be useful to anyone studying the properties and uses of cyanamid; its manufacture is treated altogether too briefly, apparently intentionally so.

Modern Technical Drawing. By **George Ellis.** Duodecimo (13 x 20 cm.), viii + 200 pages; price $2 net. London: B. T. Batsford. New York: D. Van Nostrand Co.

This strikes us as a practical and well-written book, well adapted to explain and illustrate the making of working drawings. The directions for lettering are plain and sensible, without any of the fancy half-illegible letters which so often disfigure drawings. A few directions as to making blue-prints would be a desirable addition. The chief chapters are upon othographic projection, isometric projection, oblique projection, perspective, free hand, practical geometry, lettering, and workshop drawings.

Die Theorie der Strahlung und der Quanten. Transactions of the Solvay Symposium, Oct. 30 to Nov. 3, 1911; with an appendix on the Development of the Quanten theory to August, 1913. Edited in German by A. Eucken. (Abhandlung Nr. 7 der Deutschen Bunsen-Gesellschaft für angewandte physikalische Chemie.) 16 x 24 cm, 405 pages, 24 illustrations; price 15.60 marks. Halle a. S: Wilhelm Knapp.

This is a collection of papers read at the Solvay

Congress by H. A. Lorentz, J. H. Jeans, E. Warburg, H. Rubens, M. Planck, M. Knudsen, Jean Perrin, W. Nernst, Kamerlingh Onnes, A. Sommerfeld, P. Langevin and A. Einstein, with appendix by A. Eucken. Among those taking part in the discussions may be mentioned Poincaré, Madame Curiè, Lord Rayleigh, Wien, Rutherford, Hasenöhrl and Lindemann, besides the authors of papers. There is some wonderful information and speculation in the volume, which make it highly instructive and stimulating to the student of advanced physics and chemistry. It is perhaps the best source of precise information about the Quanten hypothesis, which here appears as about half established and half in conflict with orthodox thermodynamics.

A Textbook of Chemistry. By **William A. Noyes.** Duodecimo (12 x 20 cm.), xv + 602 pages, 110 illustrations; price $2.25. New York: Henry Holt & Company.

Professor Noyes and his numerous assistants have worked three years on this book, and as it stands it embodies the experience of a whole chemical laboratory in the presentation of chemical facts and theory. In one way the book is commonplace, in that it presents the facts clearly but without enthusiasm, its tendency being rather to over-burden and discourage the student by too numerous and too detailed facts, without much appeal to his imagination. On the other hand, as a saving grace, there are frequent appeals to the student not to learn mechanically, but to analyze statements into their constituent parts, and reason out complex results from simple fundamentals.

Teachers who can incite enthusiasm for the subject by taking the students in hand and teaching the facts and theories in this analytical manner, will be able to use this text-book as a useful vade mecum in their class work.

Incidentally, we would register a warning against the tendency of text-books of chemistry to degenerate into small chemical encyclopedias. Dozens of good and useful chemical text-books have in successive editions suffered from elephantosis, with their usefulness as text-books varying in inverse proportion to their size. Even if the student learns from such monstrosities mere chemical facts (which is not true beyond peradventure), yet he probably learns from them less chemistry.

Filters and Filter Presses for the Separation of Liquids and Solids. From the German of **F. A. Bühler,** with additional matter relating to The Theory of Filtration and Filtration in Sugar Factories and Refineries, by **John Joseph Eastick.** 184 pages, 327 illus. Price, $4.80. London: Norman Rodger.

This is chiefly a descriptive book. The first part deals with filter construction. Filters with a loose filtering layer (open filters; closed filters; apparatus for reduction of iron from water; water softeners; the spirit filter), are first considered (thirty-five pages). A discussion (fifty pages) follows of filters with woven or flted filtering mediums (open filters; continuous action drainer-filter; bag or frame filters; Ehrenstein's pressure chamber filter; the filter press, its construction and different types). Brief chapters follow on filters with rigid filtering layer on separating apparatus without filtering layer, and presses for the separation of liquids and solids.

So far the book is essentially a translation of Bühler's German book and as such it should be welcome to American readers, though its usefulness is limited by the fact that almost exclusively German practice is considered. To repair this defect somewhat, the English translator has added some further chapters. First, a brief discussion on the theory of filtrations and a useful chapter of twenty-six pages on filtration in the sugar industry. In the latter a description is given of the Kelly filter press and the Sweetland filter press. The use of kieselguhr for filtering is dealt with at some length. Suction filters which have assumed such great importance in cyanide work in this country, are passed over with the remark that vacuum filters are not often used in sugar-house work because to filter rapidly the liquors must be hot, and when a high vacuum is applied, hot liquids begin to boil and thus destroy the vacuum. Descriptions of a few types of centrifuges are given, as they are essentially rotating pressure-filters.

For the list of German patents given in the original book of Bühler, a list of British patents covering the same subjects has been substituted (twelve pages), while in the section covering "Specifications of sundry filter press patents" (twenty-two pages) the text of the British specification has been followed where available. Otherwise the German version is reproduced in full.

The Silicates in Chemistry and Commerce. By Dr. **W. Asch** and Dr. **D. Asch.** Translated by **Alfred B. Searle,** with critical notes and additions. Large octavo (15 by 25 cm), xx+, 456 pages. Price, $6. New York. D. Van Nostrand Company.

The bulk of this treatise is based on a monograph prepared by the Doctors Asch upon the hexite-pentite theory of silicates. The basis of this is the assumption that six atoms of silicon with six atoms of oxygen form a closed ring having twelve free valences, or that six atoms of aluminium with six atoms of oxygen form a closed ring having six free valences. These are called "silicon hexite" and "aluminium hexite" respectively. Similarly, five atoms of each form, with oxygen, closed rings having ten or five free valences respectively, and called "silicon pentite" and "aluminium pentite" radicals.

From this starting point the authors attempt to explain the constitution and chemical characteristics of all silicates and alumino-silicates, along with many of their industrially useful physical properties. The attempt is most ambitious, painstaking and interesting, and gives many new points of view for the consideration of such subjects as the constitution and properties of clays, ultramarines, Portland cement, slags, porcelain cements, glass, enamels, porcelain.

The authors extend the principle to the study of complex salts of molybdenum and tungsten, and even devote a chapter to the consideration of the theory "as a general theory of chemical compounds," in which it is used to explain water of crystallization, metal ammonias, carbon compounds, and the constitution of the chemical atoms.

In the last section of the book the theory becomes the stereo-hexite-pentite theory, being considered stereochemically in order to combine it with the modern theory of the structure of crystals, and to explain polymorphism and isomorphism.

The work concludes with the tabulation of several hundred analyses of silicates and their comparison with the requirements of the theory.

It is difficult to characterize this tremendous piece of work in a few words. It is a mine of information on many unusual topics; it will be very interesting to the chemist and physicist, as possibly containing the seeds of many new discoveries and advances; and yet it is not convincing or altogether satisfactory. One feels that the authors have made a splendid presentation of their case, and yet leave this impression on the mind of their readers: "not proven."